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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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See Illustrated Advertisement Page 125, April 23.

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See page 17, May 7. 8305

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See page 15, May 7. 8421

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See Advertisement page 96.

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MANCHESTER WAREHOUSE—34, DEANSGATE.
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BIRMINGHAM WAREHOUSES—NILE STREET, SHEEPSCOTE STREET.
See Advertisement page 96. 8187

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London Office—12, Victoria Street, S.W.
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Packings "Redstone" "Bluestone"
GUTTA PERCHA & RUBBER, LIMITED,
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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 30ft. clear of vessel.—Apply, F. J. THEWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4638

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Engines and Dynamos could be sold separately.
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&c. &c. 7736

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Head, Wrightson & Co., LIMITED.
See Advertisement page 86, May 7. 8402

Matthew Paul & Co., Ltd. LIVERPOOL WORKS, **Dumbarton.** 7859
See Full Page Advt., page 91, April 30.

Taylor & Challen Presses. 8195
TAYLOR & CHALLEN, LD., Engineers, BIRMINGHAM
See Full Page Advertisement, April 30.

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THOMAS SUMMERSON & SONS, LTD., DARLINGTON. 7963

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REDDISH.

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THE BRITISH ALUMINIUM CO., LTD., 109, Queen Victoria St., London, E.C. 4.

See Advt. Page 126, May 7. **Steam Hammers** **Power Hammers** **Steam and Friction Drop Stamps.**
B. & S. Massey, Ltd., 8229 MANCHESTER.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 8443

South Indian Railway COMPANY, LIMITED.

On and from the 15th MAY, 1920, the OFFICES of the Company will be at:—
91, YORK STREET, WESTMINSTER, S.W. 1,
to which all communications should be addressed thereafter.
(Signed) NEVILLE PRIESTLEY,
Managing Director.
G 541

Manchester Municipal College OF TECHNOLOGY.

(UNIVERSITY OF MANCHESTER.)

Students desiring to enter upon one of the courses leading to the degree of Bachelor of Technical Science in the University of Manchester or to the University Certificate in Technology for the first time at the beginning of the Session 1920-1921 should apply not later than 20th May to the REGISTRAR, College of Technology, from whom forms of application may be obtained. A first selection of applicants will then be made.
G 426

Royal Corps of Naval CONSTRUCTORS.—A COMPETITIVE EXAMINATION for one or more

Posts as Probationary Assistant Constructor will be held at the ROYAL NAVAL COLLEGE, GREENWICH, in JUNE next.
The Regulations and full particulars of the salary, prospects of promotion, etc., may be obtained from the SECRETARY (C.B.), Admiralty, S.W. 1, to whom intending candidates must submit their names and full particulars of their educational and technical training and practical experience, not later than 17th May.
PRIVATE STUDENTS OF NAVAL ARCHITECTURE.

In conjunction with the above examination there will be a qualifying examination for the admission of Private Students of Naval Architecture to the Royal Naval College, Greenwich. Applications for the Regulations, etc., should be made as in the case of the examinations for the post of Probationary Assistant Constructors (see above).
Private Students are required to pay a fee of £30 a session whilst at the College. G 278

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successes by Correspondence Coaching. Several prizes. Sec. "O" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434, Offices of ENGINEERING.

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KNOWLES, B.Sc., Assoc. M. Inst. C.E., F.S.I., M.R.San.I., PREPARES CANDIDATES personally or by correspondence. Hundreds of successes. Courses may commence at any time.—39, Victoria St., Westminster, S.W. 8622

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A.M.I.C.E. and A.M.I.M.E.

Tuition. Also Postal Courses in Mechanical Engineering, Aircraft Design and Mathematics.—PENNINGTONS, 264, Oxford Road, Manchester.

TENDERS.

MIDLAND GREAT WESTERN RAILWAY OF IRELAND COMPANY.

OLD MATERIALS FOR SALE.

The Directors of the Midland Great Western Railway of Ireland Company are prepared to receive

Tenders for the Purchase of OLD MATERIALS.

Form of Tender giving full particulars, can be obtained on application to the Storekeeper, General Stores Department, Broadstone Station, Dublin.
Tenders must be posted in time to be received at Broadstone on Tuesday, 25th May, 1920.
By Order,
Broadstone Station, PERCY A. HAY,
11th May, 1920. Secretary.
G 519

THE GREAT INDIAN PENINSULA RAILWAY COMPANY

The Directors are prepared to receive

Tenders for the Supply of the

following STORES, namely:—

	Specification Fee.
1. Steel Work for Bridges	10/-
2. Cast-Iron Water Pipes, &c.	5/-

Specifications and Forms of Tender may be obtained at this office on payment of the fee for the Specification, which payment will not be returned.
The fee should accompany any application by post.
Tenders must be delivered in separate envelopes, sealed and addressed to the undersigned, marked "Tender for Steel Work for Bridges," or, as the case may be, not later than Eleven o'Clock a.m., on Wednesday, the 26th May, 1920.
The Directors do not bind themselves to accept the lowest or any Tender.
R. H. WALPOLE,
Secretary.
Company's Offices,
48, Copthall Avenue, E.C. 2.
London, 12th May, 1920. G 542

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD.
(PLANT AND MACHINERY SECTION).

For Sale by Public Tender.

GASHOLDERS AND TANKS,
At H.M. AIRSHIP STATION, LONGSIDE.

TWO STEEL GASHOLDERS, each 250,000 cub. feet capacity.
Three LIFTS, Spiral Guided:
Inner Lift, 68 ft. 10 in. by 22 ft.
Middle Lift, 71 ft. by 22 ft.
Outer Lift, 73 ft. 2 in. by 22 ft.
Two STEEL TANKS, 75 ft. by 22 ft. 6 in.
Reference M.K. 2456/0. Gen. 2017.
Full particulars, permit to view, and Form of Tender upon application to the CONTROLLER (D.B.I.e.), Plant and Machinery Section, Charing Cross Buildings, Embankment, W.C. 2.
Tenders to be completed and returned not later than Ten a.m., 22nd May.

NOTE:—For particulars of other Government Property for Sale, see *Surplus*, price 3d., at all Bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 179

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD
(PLANT AND MACHINERY SECTION).

FOR SALE BY TENDER.

KITE BALLOON MACHINERY,
At HOUTON BAY, ORKNEY ISLANDS.

Tenders are Invited for the

following:—
One 28 HP. MOTOR, 440 volts, D.C. Makers: Messrs. Scott. Complete with Starter and Switch.
Two PUMPS (Lee Howl Mechanical).
One PUMP, Worthington Vertical Triplex 5½ in. by 8 in.
One GAS PLANT, "B" type.
Consisting of cylindrical Generator, Coke scrubber, two Soda mixing tanks, mechanically operated stirring gear in cylindrical hopper and Generator. Wet feed Silicol, admission gear, overhead water tank, hand crane. Water cooling tower, complete with circulating pump and motor, and all pipes in connection to suit.
One 44 HP. DORMAN PETROL ENGINE, 130 mm. by 140 mm. stroke.
Two Compressors, Murray Workman, three stage type to compress 2500 cubic feet of free hydrogen per hour to a pressure of 1800 lbs. per square inch, for charging hydrogen cylinders.
Full particulars and Tender Forms may be obtained on application to the CONTROLLER, Plant and Machinery Section, Charing Cross Embankment Buildings, London, W.C. 2.
TENDERS CLOSE on JUNE 1ST, 1920.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all Bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 426

G. R.

MINISTRY OF MUNITIONS.

BY DIRECTION OF THE DISPOSAL BOARD.
(PLANT AND MACHINERY SECTION).

For Sale by Public Tender,

TOLUOL PLANTS,
At MANCHESTER CORPORATION GASWORKS, Bradford Road, Manchester.

Six Tower Scrubbers, Carburettors, Steel frame Benzol House, Crude Still, Primary and Secondary Rectification Stills, Oil and Water Coolers, Pumps, Two Boilers and One Pump, Chimney and Steel frame Boiler House, etc.

At NEWPSHEND WORKS of the SHEFFIELD GAS CO.

Oil Tanks, Coils for Heat Exchanger, Oil Still, Pumps, Coolers, Condensers, Benzol Still, Benzol Washers, Acid and Soda Tanks, Rectification Still, Petrol Pumps, and Steel Frame Benzol and Exhauster Houses.

At GRIMESTHORPE WORKS of the SHEFFIELD GAS CO.

Heat Exchanger, Pre Heater, Oil Still, Receiver, Cooler, Condenser, Benzol Condensers, Pumps, and Steel frame Benzol House.

At GRANTON GASWORKS, EDINBURGH, and LEITH COMMISSIONERS.

Heat Exchangers, Oil Pumps, Coolers, Benzol Condensers, Crystallising Tanks, Pumps, Storage Tanks, etc.

At PROVAN GASWORKS, GLASGOW.

Heat Exchangers, Oil Pumps, Cooler, Pre Heater, Still, Benzol Still and Condenser, Condensers and Chimneys, Naphthalene Separators, Rectification Column, Benzol, Toluol, and Solvent Condensers, Pumps, Steel frame Plant House, Heavy Oil Still, Coolers, Spares, etc.

Detailed particulars, permit to View and Tender Forms, can be obtained on application to CONTROLLER, D.B.I.H., Plant and Machinery Section, Charing Cross Huts, Embankment, W.C. 2.
Tenders to be returned not later than 10 a.m. on the 29th May, 1920.

NOTE.—For particulars of other Government Property for Sale, see *Surplus*, price 3d. at all bookstalls; or by quarterly subscription of 2s. post free in the United Kingdom, payable in advance to the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. G 296

LONDON COUNTY COUNCIL.

The Council invites

Tenders for the Supply and

DELIVERY of about 5500 TONS of STANDARD STEEL GIRDER TRAMWAY TRACK RAILS, LIPLESS TRACK RAILS, and RENEWABLE GUARD RAILS with Fastenings.
Persons desiring to Tender may obtain the drawings, specifications, bills of quantities, form of Tender, and other particulars on application to the CHIEF ENGINEER of the Council, at the County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of the sum of £2. This amount will be returnable only if the Tenderer shall have sent in a bona fide Tender and shall not have withdrawn the same. Full particulars may be obtained on application at the County Hall before the payment of the fee.
Tenders must be on the official form. No Tender received after Four p.m., on Monday, 7th June, 1920, will be considered. The Council does not bind itself to accept the lowest or any Tender.
JAMES BIRD,
Clerk of the London County Council.
G 530

LONDON COUNTY COUNCIL.

The Council invites

Tenders for the Manufacture,

DELIVERY and ERECTION at Abbey Mills Pumping Station, West Ham, London, E., of THREE 30-inch and TWO 16-inch CENTRIFUGAL PUMPS (driven direct by steam engine supplied under another Contract), each larger pump to be capable of raising 15,000 gallons of water a minute 51 ft. high, when running at a speed of 200 revolutions per minute, and each smaller pump to be capable of raising 4480 gallons of water a minute 51 ft. high, when running at a speed of 285 revolutions a minute.
Persons desiring to Tender may obtain the Specification, Drawings, Form of Tender, etc., on application to the CHIEF ENGINEER, at the County Hall, Spring Gardens, S.W.1, upon payment to the Cashier of the Council, of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the Drawings, Specification and other Contract Documents, may be inspected at the County Hall, before the payment of the fee.
Tenders must be upon the Official Forms and the instructions therein must be strictly complied with. No Tender received after Four p.m., on Monday, 14th June, 1920, will be considered. The Council does not bind itself to accept the lowest or any Tender. G 402
JAMES BIRD,
Clerk of the London County Council.

CITY OF BRADFORD.

ESHOLT SEWAGE DISPOSAL WORKS.

CONTRACT No. 32.

STEEL FRAMEWORK OF BUILDINGS, Etc.

The Corporation are prepared to receive

Tenders for the Supply,

DELIVERY and ERECTION of the STEEL FRAMEWORK of a Building with a flat roof, 50 ft. long by 44 ft. wide by 40 ft. high, together with STEEL ROOF TRUSSES for a Building 68 ft. 6 in. long by 34 ft. wide.
Drawings may be seen and copies of Specification, Quantities and Form of Tender may be obtained on and after Wednesday the 26th May, 1920, at the office of Mr. JOSEPH GARFIELD, M. Inst. C.E., Sewageworks Engineer, Esholt Hall, Shipley (station, Apperley Bridge, Midland Railway).
Tenders, endorsed "Esholt Sewage Disposal Works—Contract No. 32," must be delivered at the office of the undersigned not later than Nine a.m., on Wednesday, the 2nd June, 1920.
The Contract will be subject to the Fair Contracts Clauses of the Corporation, which may be seen at the Sewageworks Engineer's Office, and which the accepted Contractor will be required to sign.
The Corporation do not bind themselves to accept the lowest or any Tender.
NORMAN L. FLEMING,
Town Clerk.
Town Hall,
Bradford.
May, 1920. G 509

TO CONTRACTORS.

GOSPORT AND ALVERSTOKE URBAN DISTRICT COUNCIL.

CONSTRUCTION OF LANDING STAGE, WHARF AND OTHER WORKS.

The Gosport and Alverstoke Urban District Council are prepared to receive

Tenders for the Construction

at Gosport, Hants, of a FLOATING LANDING STAGE, 200 ft. long by 30 ft. wide, connected with the shore by a Bridge 130 ft. long by 20 ft. wide, and Approach Roads leading thereto; about 550 lineal feet of Reinforced Concrete Retaining Walls to enclose portions of Gosport Hard and the adjoining foreshore; the filling in of the area so enclosed; the Removal of Gosport Hard; a Reinforced Concrete Wharf 300 ft. long by 100 ft. wide at Harbour Road; the necessary Dredging for the Landing-Stage and Wharf, and other contingent works.
The Contract Drawings and Specification may be seen at the Offices of the Engineers, SIR JOHN WOLFE-BARRY, LYSTER & PARTNERS, Dartmouth House, 2, Queen Anne's Gate, Westminster, S.W. 1, on and after Wednesday, 12th May, between the hours of Eleven and Four, and copies of the Drawings and Specification, together with a Schedule of Quantities and Form of Tender, may be obtained there upon payment of Five Guineas. This sum will be repaid by the Council upon receipt of a *bona fide* Tender, accompanied by the Specification and Drawings, which are to be returned with the Tender.
Tenders endorsed "Tender for Landing Stage, &c.," must be delivered under seal at the Office of the Clerk to the Gosport and Alverstoke Urban District Council, Council Offices, Gosport, Hants, on or before noon on Saturday, 5th June.
The lowest Tender will not necessarily be accepted.
H. R. MANGNALL,
Clerk to the Council.
Council Offices, Gosport.
4th May, 1920. G 389

AUCKLAND HARBOUR BOARD, NEW ZEALAND.

Tenders are Invited for the

CONSTRUCTION and SUPPLY of Five 1 Ton ELECTRIC CAPSTANS and SPARES for same.
Specifications and Drawings can be obtained on payment of a deposit of Two Guineas at the Office of the Board's Agents, Messrs. W. AND A. MCARTHUR, LTD., 18-19, Silk Street, Cripplegate, London, E.C. 2.
Tenders to reach Auckland by noon, on September 1st, 1920. F 735

METROPOLITAN BOROUGH OF SHOREDITCH.

Plant for Sale.—

One 800 Kw. C.C. GENERATING SET, complete, consisting of Slow Speed Marine Type Compound Steam Engine, manufactured by the Wallsend Slipway Co., coupled direct to Westinghouse Generator, 1100-1200 volts, complete with Condenser, Air and Circulating Pumps, Oil Separator, etc., etc.
One Davis Perrett Type, ELECTRO-MECHANICAL OIL SEPARATOR, complete with Tanks, Pressure Filter Press, etc.
Particulars conditions and forms of Tender may be obtained upon application to
C. NEWTON RUSSELL,
Borough Electrical Engineer & Manager.
Electricity Department,
Coronet Street,
Shoreditch, N. 1. G 498

TO ENGINEERS AND OTHERS.

THE METROPOLITAN ASYLUMS BOARD invite

Tenders for Installation of

NEW STEAM BOILER, IRONING MACHINE, PIPEWORK and ENGINEERING WORK for Laundry, at Princess Mary's Hospital, Cliftonville, Margate, Kent, in accordance with Drawing and Specification prepared by Mr. T. COOPER, M.Inst.C.E., M.I.Mech.E., Engineer-in-Chief, the Drawing, Specification and Form of Tender may be inspected at the Office of the Board, Embankment, E.C.4, on and after 10 a.m., on Thursday, 13th May, 1920, and the Drawing, Specification and Form of Tender can then be obtained upon payment of a deposit of £1. The amount of the deposit will be returned only after the receipt of a *bona fide* Tender, sent in accordance with the instructions on the Form of Tender, and after the Specification and the Drawing have been returned.
Tenders, addressed as noted on the Form, must be delivered at the Office of Board, not later than 2.30 p.m., on Thursday, 27th May, 1920. G 480
By Order, DUNCOMBE MANN,
Clerk to the Board.

LONDON COUNTY COUNCIL.

The Council invites

Tenders for the Manufacture,

DELIVERY and ERECTION at Abbey Mills Pumping Station, West Ham, London, E., of THREE TRIPLE EXPANSION and TWO CONPOUND MAIN-DRIVING STEAM ENGINES of the vertical enclosed type, and TWO SURFACE-CONDENSING SETS. Each triple expansion engine to be capable of developing 400 I.H.P. when running at a speed of 200 revolutions a minute and each compound engine 120 I.H.P. when running at a speed of 285 revolutions, the steam pressure being 155 lb. absolute a square inch in each case.
Persons desiring to tender may obtain the Specifications, Bills of Quantities, Form of Tender, etc., on application to the CHIEF ENGINEER, at the County Hall, Spring Gardens, S.W. 1, upon payment to the Cashier of the Council of the sum of £3. This amount will be returnable only if the Tenderer shall have sent in a *bona fide* Tender, and shall not have withdrawn the same. Full particulars of the work may be obtained on personal application, and the drawings, specification and other contract documents may be inspected at the County Hall before the payment of the fee.
Tenders must be upon the official forms and the instructions therein must be strictly complied with. No Tender received after Four p.m., on Monday, 14th June, 1920, will be considered. The Council does not bind itself to accept the lowest or any Tender. G 463
JAMES BIRD,
Clerk of the London County Council.

COUNTY BOROUGH OF LONDONDERRY.
GLENS OF BANAGHER WATER SCHEME.

CAST IRON PIPES.

The Corporation of the County Borough of Londonderry are prepared to receive

Tenders from Competent

Persons for SUPPLYING and DELIVERING on the Quay at Londonderry of about Three Thousand Two Hundred and Fifty (3,250) lineal yards of CAST IRON WATER MAINS of 30in. internal diameter, together with a number of BENDS, TAPERS, COLLARS and other SPECIALS, cast in accordance with the requirements of the current specification of the British Engineering Standards Committee.
Specification, Schedule, Form of Tender and any other particulars required may be obtained from Mr. M. A. Robinson, City Engineer, Guildhall.
Tenders sealed and endorsed "Banagher Water Pipes" are to be lodged at the City Engineer's Office not later than TWELVE noon on Monday, 7th June, 1920.
Tenders sent by post must be registered and for those delivered by hand a receipt will be given.
The Corporation do not bind themselves to accept the lowest or any of the Tenders.
By order,
F. HENRY MILLER,
Town Clerk.
Guildhall, Londonderry.
11th May, 1920. G 560

APPOINTMENTS OPEN.

BOROUGH POLYTECHNIC INSTITUTE, LONDON, S.E. 1.

Applications are Invited for

the POSITION of ENGINEERING INSTRUCTOR at the above named Institute for fitting and light forging, and Evening Classes in Pattern Making. Applicants must have been regularly trained and possess some teaching experience. Salary £275 by £10 to £350. For additional information and forms of application send stamped addressed foolscap envelope.
C. T. MILLIS,
Principal. G 506

THE WORKS OF MESSRS. MARSHALL, SONS AND CO., LTD., GAINSBOROUGH.

THE fame of Gainsborough, Lincolnshire, has been spread to the far corners of the earth in two widely different associations. Since the middle Victorian era, under the name of St. Ogg's, half the reading world has been familiar with George Eliot's picture of its life and ways in the first half of the nineteenth century. The scenes in the "Mill on the Floss" were cast in years when the introduction of steam to the mills threatened to reduce their romance, but promised to improve their profits. But our conception of romance changes with the years. To-day—we have Kipling for our authority—Romance has an oil can, and his hand is on a lever, in which case Romance thrives in the heart of the old town still, in the works of Messrs. Marshall, Sons and Co., Limited, whose first small beginnings on Pingle Hill Walk date from about the time of the closing incidents of George Eliot's novel.

Fig. 1.

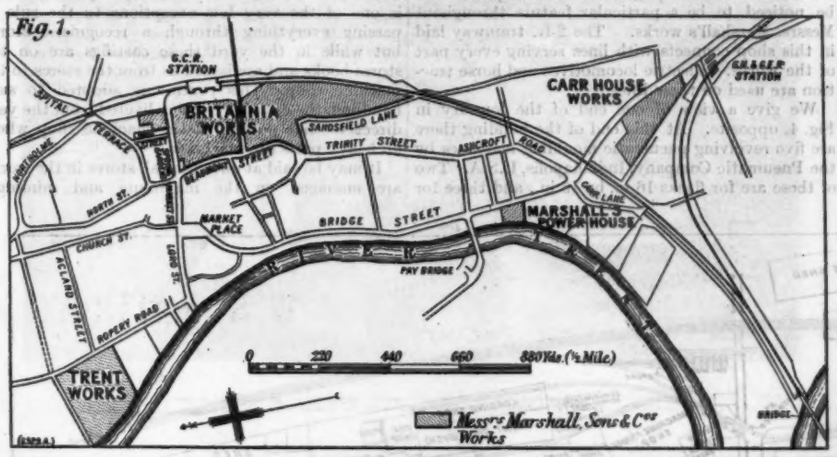
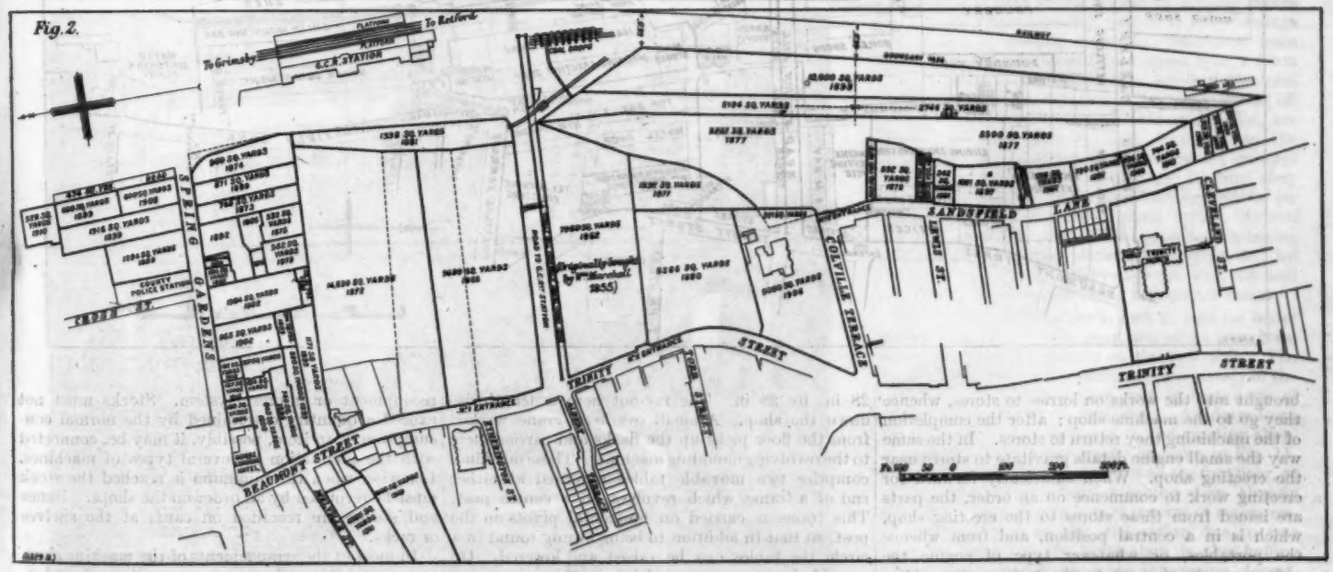


Fig. 2.



As will be seen from the small plan of the town given in Fig. 1, above, these works, omitting the new power-house, are in three main sections. Of these, the largest is the Britannia Works, the other two being the Trent Works and the Carr House Works. The first named works is divided again into two almost independent parts, known as the North Side and the South Side; these two sections are devoted to separate products.

The Britannia Works area was acquired piecemeal at different times as the business expanded, the commencement being made in a shop which exists to the present day on the south side of Pingle Hill Walk. This original shop now forms part of a large smith shop and store. The plan in Fig. 2 gives, in an interesting manner, an idea of the way in which the Britannia Works have developed. The property was mostly dwelling-houses and could only be obtained in small sections. The works have in course of time occupied the whole of the area bounded by Spring Gardens, Beaumont-street, Sandsfield-lane and the Great Central Railway, with the exception of one small corner at the junction of the two streets first named. The Trent Works area was acquired in 1892, and the Carr House area in 1911.

We may briefly summarise the history of the firm as follows: It was established in 1848, and in 1862 was formed into a limited liability company. In 1870 the area occupied was about 4½ acres, and the number of men employed was about 550. By 1880 the works had expanded to 15½ acres with a roll of 1,310 men.* Ten years later the number of employees was over 2,200, and the area had increased to 20 acres. In another ten years it was 34 acres with about 3,000 employees on the roll. In 1910 the area had reached 39 acres and the number of employees was just over 4,000. At the commencement of the war there were about 5,000 men employed and about 2,000 joined up in the early stages of the conflict. The present area is about 45 acres, though this space is so well made use of that the actual working area is considerably in excess of that figure.

During the seventy-two years of the firm's existence they have turned out about 175,000 engines and boilers, representing some 4,000,000 i.h.p.

* The Institution of Mechanical Engineers which is to visit Messrs. Marshalls Works during its forthcoming summer meeting at Lincoln, last visited the Gainsborough firm in 1885, on which occasion we gave a description of the works as they then existed (*vide* vol. xl, page 117). A comparison between the former account and that given in the present articles reveals many points of interest in the transformation which has taken place in the interval.

The products of Messrs. Marshall, Sons and Co., Limited, are so well known that it is scarcely necessary to enumerate them, but in order to make our description of the works clear it will be as well to refer here to some of them. We may summarise them by stating that the firm turns out a standardised range of sizes of steam tractors and traction engines, road rollers, portable engines, semi-portables, locomobiles, fixed engines, vertical and horizontal, from small sizes up to 2,000 h.p. drop-valve mill engines, oil engines (two-cycle horizontal), vertical, locomotive, Lancashire and allied types of boilers, threshing machines, maize shellers, elevators, &c., tea machinery, flax machinery, decorticators for fibres, &c.

These products will be seen to group themselves to some extent, and the works are laid out accordingly. For instance, the Britannia Works North Side are engine works, and here are produced all the types and classes of engines manufactured by the firm, with their boilers in the case of tractors, traction engines, portables, &c. With something like 14 absolutely distinct classes of machines, each with a large range of sizes, the amount and variety of the work passing through these shops is, of course, very considerable. The South Side of the Britannia Works is regularly devoted to three more or less distinct products, though in this case some of the shops cater for both North and South Sides. A large portion of these South Side works is given over to the construction of threshing machines, maize shellers and elevators—all machines embodying a good deal of wood work and a lot of small metal detail parts. The remaining shops are mainly devoted to the construction of tea and flax machinery. The Trent Works, again, are wood working machine shops and stores, while the other detached plant, the Carr House Works, which during the war was utilised for building "Bristol Fighter" aeroplanes, is now used as a finishing, painting, packing and despatching depot.

BRITANNIA WORKS—NORTH SIDE.

We commence our description with the shops of the Britannia Works. In following this, it must be borne in mind that these shops have to deal with the manufacture of portable engines, road rollers, traction engines, locomobiles, fixed engines, &c.

The site of the Britannia Works slopes gradually from the town, which is on low-lying ground, up towards the Great Central Railway, which comes into the town on a much higher level. This difference of levels amounts to about 25 ft. between the front and back of the present works area. Beyond the railway the ground continues to rise. As the works have spread they have eaten more and more into the hillside, and, while use has been made of this, extension has naturally proved expensive, and the planning of the shops somewhat difficult.

It has not been, however, without some compensation, as will be gathered when we come to the more detailed discussion of the lay-out.

The works are served by the Great Central Railway, whose sidings run into them, as shown in Fig. 3. Their high level is made use of both in the foundry and boiler shop, into which lines run.

It will be convenient to trace the material round the works on its regular route, commencing with the raw material and finishing with the product painted and packed for despatch. This routeing in Messrs. Marshall's works is very definitely and systematically arranged. Before describing the shops themselves we may give a few notes on the system, which will enable the subsequent references to the shops to be more easily understood. In the North Side works everything gravitates towards the erecting and testing shops, and each department feeds and draws from stores as required. The raw material coming into the foundry is converted into castings, which are fettled and then transferred to stores. From these they go into the machine shop, where all the necessary work is done on them, when they are returned again to stores. At the same time plates &c., are received by rail in the boiler shop and the required boilers are constructed. The larger forgings, purchased outside, arrive by rail, and are brought into the works on lorries to stores, whence they go to the machine shop; after the completion of the machining they return to stores. In the same way the small engine details gravitate to stores near the erecting shop. When sufficiently forward for erecting work to commence on an order, the parts are issued from these stores to the erecting shop, which is in a central position, and from whence the portables, or whatever type of engine the order consists of, pass to the testing pits. After satisfactory tests they are hauled away to the Carr House Works, for painting, packing and despatch.

Having summarised the system we may proceed to a more detailed description of the shops themselves, following much the same routeing. As already mentioned the raw material is received in the foundry on a high-level siding under cover. The sand, &c., has merely to be shovelled from the trucks through traps in the floor, to drop to a landing on which mills are arranged. From these it passes by chutes to mixers, &c., on the foundry floor. Similarly the pig and coke required for the cupolas falls to the level of the charging platform, so that all hoisting is obviated. There are four cupolas, three of 4 ft. 6 in. diameter, of a capacity of 10 tons per hour, and one of 3 ft. diameter, giving 6 tons per hour. The metal is drawn off on the ground floor level. The foundry consists of three bays, 315 ft. long by 53 ft. wide. The heavy work is done in the middle bay near the cupola end. The other two bays are used for light work, and in general the principle is adopted that the lighter the work the further it is done from the cupola, in order to facilitate the handling of the metal. In the retaining wall under the railway siding referred to, an interesting use is made of the arches which form part of the masonry structure of this building, which is built into the hill. These retaining-wall arches run all the length of the shop, on the foundry floor level. Fourteen of them are used as core ovens, being eminently suited for this purpose. These ovens are gas-fired, there being four Mason gas producers, also situated in arches between the ovens. The foundry is well equipped with eight overhead electric cranes, ranging from half a ton to 30 tons, and other handling appliances. This liberal provision of crane power will be noticed to be a particular feature throughout Messrs. Marshall's works. The 2-ft. tramway laid in this shop connects with lines serving every part of the works. Electric locomotives and horse traction are used on these lines.

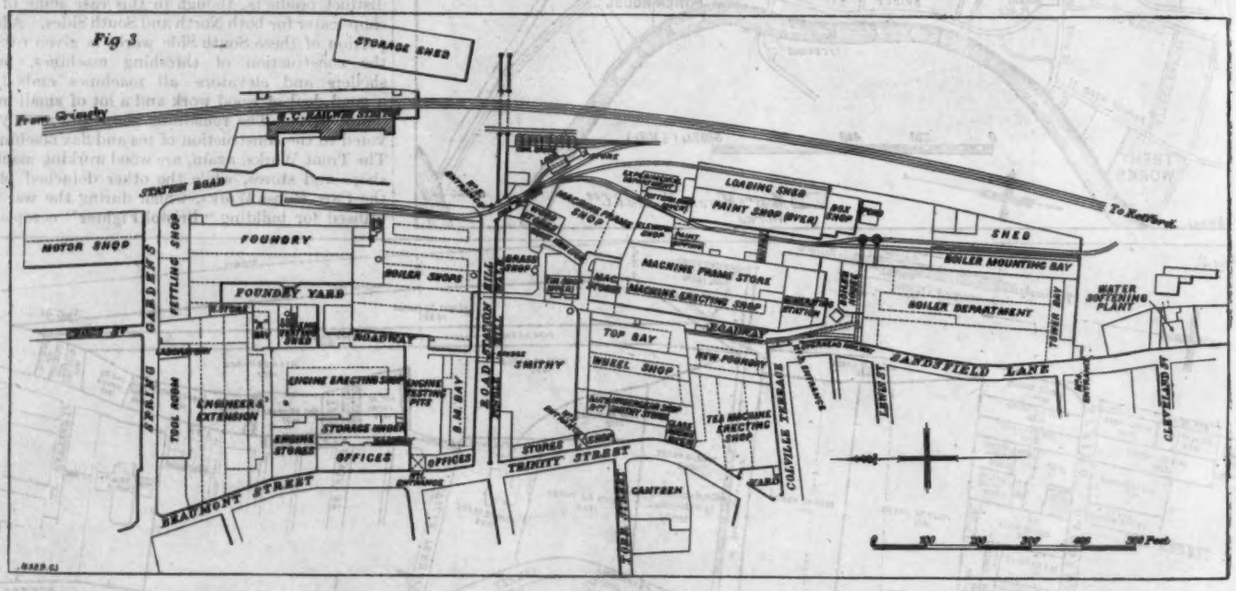
We give a view of one end of the foundry in Fig. 4, opposite. At this end of the building there are five revolving pneumatic moulding machines by the Pneumatic Company, Indianapolis, U.S.A. Two of these are for flasks 16 in. by 16 in., and three for 28 in. by 28 in. The lay-out here is lengthwise down the shop. A small overhead crane worked from the floor picks up the flasks and carries them to the revolving moulding machines. These machines comprise two movable tables mounted at either end of a frame which revolves on a centre post. This frame is carried on horizontal pivots on the post, so that in addition to being swung round in a circle the tables can be raised and lowered. On one side is a press operated by air, the ram coming up from below and pressing the table and the filled flask upon it against a fixed frame above. Work proceeds on two moulds at once, one being rammed by air power while the other is filling with sand drawn by a chute from a hopper overhead. When rammed the crane again takes hold of the flask and carries it off to the floor. The finished moulds are arranged in lines, as shown in our illustration, and, after pouring, the castings are shaken out, and the sand is shovelled to the conveyor, which carries it down the shop to a bucket conveyor, which in turn lifts it to the hopper level and there discharges it.

There are six Tabor moulding machines in the bay for light work, two of them being portable, and, in addition, hand machines. A floor above one part of the foundry accommodates women core makers. Adjoining the foundry is, on one side, a foundry yard, spanned to full length by a 12-ton electric crane, and, at the end, a fettling shop. All the lighter work passes direct from the foundry to the fettling shop, which is provided with a full equipment of rumblers, sand blast, &c. Near by a conveyor lifts the refuse from the fettling shop and foundry to a hopper, whence it is carted away. The fettled castings pass to a store for engine parts. In this store, provided with two overhead cranes, are to be found cylinders of all sizes and types, engine frames and guides, and all manner of details, some rough from the fettling shop and others completely finished. This store not only receives the rough castings from the fettling shop, but issues them to the machine and fitting shops, whence they afterwards return finished, to be ultimately sent out to the erecting shop. The larger castings made at one end of the foundry are passed through a large doorway into the yard, where they are fettled and temporarily stored, being subsequently passed direct into the large machine shop adjoining. This is one of the very few exceptions to the rule of passing everything through a recognised store; but while in the yard these castings are on the stores books and are issued as from the stores to the machine shop. This routine is adopted to save handling, the castings being delivered from the yard direct to that portion of the machine shop where all heavy parts are machined.

It may be said at once that all stores in the works are managed on the maximum and minimum recoupment or imprest system. Stocks must not exceed a quantity determined by the normal consumption of an item, possibly, it may be, connected with the production of several types of machines. Likewise, when the minimum is reached the stock must be recouped by an order on the shops. Issues and stocks are recorded on cards at the shelves or racks.

In most of the arrangements of the machine shop, two views of which are given in Figs. 7 and 8, Plate XXXIV, the tools have been grouped according to their type. Thus the planing machines are together; the milling machines, the boring machines, slotters, drills, lathes, &c., are all in their sections. At the point where the large castings are dealt with, however, all the machines required for them are grouped. Thus, there is in this case a collection of such tools as side planers, vertical mills, keyseaters, &c., grouped around pits laid out for dealing with anything up to 30-ton flywheels, 25 ft. in diameter. In Fig. 8, Plate XXXIV, which shows this section of the machine shop, will be seen a flywheel standing in a pit. The half wheels are planed on the adjoining side planer, and the wheel is turned on a large Craven vertical mill close by, illustrated in Fig. 5; this machine will take a 25-ft. flywheel. The wheel is mounted on a revolving table. The tools are carried in slides with vertical motion, mounted on two columns, which can be racked towards or away from the centre on heavy beds. A vertical boring bar is also fitted, being driven

Fig 3



THE BRITANNIA WORKS, GAINSBOROUGH.

FIG. 4. SOUTH END OF MAIN FOUNDRY.

FIG. 5. FLYWHEEL TURNING AND BORING MILL IN MACHINE SHOP.

from below and carried at the upper end in the large arm steady shown.

The large castings, when machined, are again subjected to special treatment to obviate handling, being sent direct into the erecting shops after machining, instead of to intermediate stores. The machine shop consists of four bays, each 350 ft. long by 45 ft. wide, and is provided with 7 overhead cranes varying from 3 tons to 30 tons capacity, as well as jib cranes, &c. Castings are issued from the stores already described, and are marked off and machined, and then returned to these stores again. In the case of cylinders they are next sent into the side bay for all the necessary fitting to be done on them, after which they are transferred to stores in the erecting shop.

This machine shop handles all the heavier work for portables, rollers, traction engines, and fixed engines. It possesses a number of interesting features. The main shafting is at a level of 21 ft. from the ground, driven from motors on platforms 12 ft. from the ground. The countershafts are arranged on girders 12 ft. from the ground level. Each motor drives a length of about 50 ft. of shafting, so that the machines may be run in a series of groups in the event of special work being required. The largest machines only have individual motor drives, as well as a few awkwardly placed for belt-driving. The lavish provision of crane power is a special feature of this shop. In addition to overhead cranes all the larger machines have electric jib cranes arranged over them, so that the machinist is largely independent of the travelling crane service. Nor is this all. At one end of the shop, where crank work is concentrated, an overhead runway is arranged to every part of the floor where any of this work is done, with a series of branches to all machines engaged on it and leading to and from the stores.

The stores now referred to are on the Beaumont-street side, situated between the machine shop and the offices. These stores, served by electric cranes of 1 ton and 2 tons capacity, receive by lorry forgings for cranks, connecting rods, &c., purchased from outside firms. The store has an upper floor, a 1-ton electric elevator communicating between the two. Inside this store, on the ground floor, is a cutting off and centering department, and the cranks, &c., are dealt with here prior to being sent out to the machines. All machines for this work are grouped within easy reach of the end of the machine shop nearest this store. There are ordinary lathes for shafts, &c., and horizontal crank lathes, vertical turning machines for crank journals, grinding machines for finishing, planes and shapers, &c., for the webs, and so on. Keyways are also cut and the cranks fettled before being returned to stores.

The smaller machine work, such as that for boiler mountings, valves, valve gear, and all motion, brass work, &c., is done upstairs on the first floor. The shops where this work is performed are mostly in the vicinity of the erecting shop, and, in fact, some of them form a gallery to that shop. All draw from and feed into stores adjacent to the erecting shop. A view in one of these stores is given in Fig. 11, Plate XXXVI. The brass shop is on the first floor, at the east end of the large machine shop already described. This shop is now in process of rearrangement subsequent to the dislocation due to war work. Adjacent to the brass shop is the buffing department. Among the more interesting departments upstairs are the valve-testing section, the gauge-room and the tool-room and new tool department. A view of the valve-testing benches is given in Fig. 12, Plate XXXVI. Each bench is provided with steam pressure at 150 lb. per square inch, and with an indicating gauge. There are eight double tables in the middle of this shop, each fitted with steam supply and exhaust. The safety valves and large mountings are bolted to standard flanges which are clamped down to the tables. Governors are tested on a pipe on a bench, as shown. Hydraulic power is also provided for subjecting fittings to a water test. The gauge room where the standard limit gauges for the works are kept in a very systematic way calls for no special remark. The new tool department will be referred to later. All the above fitting and machine shops turn their

products over to stores, which are, in every case, not far away and on the same level.

While this work is being prepared in the engine department, corresponding orders pass through the boiler shop. Here as in the case of the foundry, all the material in the form of plates, &c., comes in trucks right into high-level stores. It is unloaded and handled by walking-jib cranes of 4 tons and 2 tons capacity. The material is marked off and passed down to the floor below into the plating bay, where it is cut, punched, drilled and rolled. It next passes to the assembling section, and then on for drilling, riveting, &c. The boiler shop is conspicuous for its crane arrangements. The shop is divided by high walls pierced by arches, into five bays, each 250 ft. long by 40 ft. wide. The outside bays are served by overhead travelling cranes running down the shop, of one of which a view is given in Fig. 9, Plate XXXV. The centre bay is provided with a series of traversing crabs working on girders stretching across the shop and with jib cranes at the arch openings. These cranes vary from 2 tons to 12 tons capacity. Stay-bolt drilling is done by a machine in the gallery of this shop, and the hydraulic testing of the boilers is carried out in a gallery at the further end. A notable machine in this shop is a large planing machine, Fig. 6, annexed, for truing the cylinder and crank-bearing seatings on boilers of the portable engine type. This machine will accommodate the largest portable boiler made by the firm. It consists of two beds raised on columns about 9 ft. 8 in. above the ground, over which is traversed a slide carrying the tool box. The slide is worked along the machine by two screws, one contained in each bed and driven by belt from line-shafting. Automatic or hand-cross feed is provided for the tool-box on the main slide. The boiler is packed up on a cast-iron girder at the fire-box end, this girder being capable of being raised or lowered by power. The other end is packed on blocks and levelled. As the seatings are made of pressed steel plate, preparation of this kind for the engine parts is, of course, necessary.

This boiler shop has three hydraulic presses, the largest having a 9-ft. table. The largest of the three furnaces for these presses can take plates up to 10 ft. 6 in. The furnaces are gas-fired by a producer in the corner of the shop receiving its coal from a hopper below the railway siding above mentioned. Among the plates being incorporated in boilers in this shop are to be seen innumerable pressed fire-box sheets, with an X-form of corrugated roof, introduced by Messrs. Marshall, and described in ENGINEERING in 1912.* Another interesting example of flanging is to be noticed in certain front tube plates, in which Messrs. Marshall are now pressing an internal horizontal corrugation above the tube area, as a stiffener for this unstayed portion of the plate. This boiler shop is almost wholly occupied with locomotive type boilers.

The completed boilers are taken either to the erecting shop or to the boiler mounting bay. Of the latter little need be said, except that boilers of the locomotive type for independent orders—*i.e.*, not forming part of the combined engine and boiler unit—are finished here, and the mountings fitted. Feed water heaters are also completed in this bay.

The erecting shop for portables, &c., has a floor of 36,000 sq. ft. We give a general view of it in Fig. 10, Plate XXXV. The number of engines that can be put down at one time on the floor may be gathered from this view. Portables are accommodated under one gallery. Under the other gallery a certain number of machines are situated, such as are required for a few operations which can best be done as the engines are assembled. The stores already referred to feed this shop, issuing complete sets of parts according to the order in hand. Here, again, the crane provision is on a lavish scale, and the men have no cause to fear delay in getting assistance of this class. The hoisting capacity ranges from 1 ton to 12 tons. Portables, tractors and rollers, when finished, are picked up by an overhead travelling crane and deposited at the south end of the shops, whence they are hauled out to the engine-testing pits, of which we give a view in Fig. 13, Plate XXXVI. There are 16 pits in all, 11 being usually occupied by portables and tractors and 5 by rollers. Each pit is partly separated from that on either side of it by wing walls. Swivel telescope chimneys are suspended over head, and fit on to the chimneys of the engines under test. Coal is delivered from an overhead hopper to each pit; this point we shall have occasion to refer to again. An ash pit is provided for each engine and the necessary water supply, &c. Stocks of fire-bars are kept stored close by, and the engine is fitted with a complete set on coming from the erecting shop. This testing shop is 200 ft. long by 70 ft. wide, and is served by a 25-ton overhead travelling crane, 30 ft. above the floor level. From this shop the engines are taken to Carr House Works, for painting, packing and despatch.

Fixed engines of the horizontal and vertical types are also erected in shops in a central position, fed from the various stores in the same way as described above. Here the engines are built up on cast-iron bases or stools. The latter are movable along rail beds arranged on the floor, and can be placed to suit. Once in position the small units can be very expeditiously erected upon them. It will be noted that they are at a convenient height for working. The small verticals are treated in a similar manner. Fig. 15, Plate XXXVII, shows a bay where horizontal engines up to 250 h.p. are assembled, while in the testing shop for stationary engines, also in the same quarter of the works, the biggest compounds built by the firm up to 2,000 i.h.p. are erected and tested under steam as shown in Fig. 14, Plate XXXVI. This shop is provided with a Galloway boiler, 30 ft. by 8 ft., working at 100 lb. pressure, and two Marshall-Heine 200-h.p. water-tube boilers working at 160 lb. pressure. Softened feed water is supplied by two Pearn pumps, and is passed through a Marshall feed heater. A complete system of steam-reducing valves, with swivel connections, ensures convenient supply to the engines under test. These engines also subsequently go to the Carr House Works for painting and despatch.

There now only remains to be mentioned among the north side shops the repair and reserve department and the tool-room. The former department is concerned with general repairs to existing plant undertaken by the firm for customers in the district, &c. The reserve section deals with spares and duplicates required for engines already supplied to customers. We are not in a position to say much regarding the tool-room arrangements, as this part of the organisation is in a transition stage at the moment. The tool-room at present occupies a shop on the first floor, which it has far outgrown, and it is now being transferred to a two-storied building on the Spring Gardens side of the works. The new shop is exceedingly light and roomy, and will provide almost four times the floor space of the old tool-room. The heavier machines are being arranged on the ground floor and the lighter above; a large hoist communicates between the two. Two lines of main shafting are provided below and one above. On the top floor there will also be a drawing office for tools, jigs, &c. It is the custom in these works not only to make all jigs in the tool room, but to make new machines required in the works, and to try them out in this shop before erection in the machine shop. Records are kept of their performance under these tests, and these serve as a check on shop performance and as a guide in settling piece prices, &c. The system of issuing standard-shaped tools for the various jobs is being increasingly adopted, though tool smiths still work in a small annexe to the machine-shop gallery supplying that shop direct with tools. The works laboratory is adjacent to the new tool-room. It is equipped with an Olsen 50-ton testing machine, a 2-ton transverse testing machine, Shore scleroscope, Fery optical pyrometer, chemical apparatus, &c. Before leaving the north side works we may mention that a new shop, known as the motor shop, is being arranged for tea machinery and oil-engine erection. This shop is now being re-equipped, subsequent to its utilisation on shell work during the war. It is situated on the north side of Spring Gardens, being the only shop at present on that side of that road. It consists of two bays, 235 ft. long by 46 ft. wide, and is served by overhead cranes of 8 tons and 3 tons capacity.

FIG. 6. BOILER SEATING PLANING MACHINE.

BRITANNIA WORKS—SOUTH SIDE.

The same systematic routeing is to be found in the South Side shops, which are connected with the North Side by a large subway passing under Pingle Hill Walk. The area occupied by these shops, as may be seen in Fig. 3 (page 636) is bounded by irregular streets, and their shape and distribution are

* See *Engineering*, Vol. XCIV, page 303.

unavoidably not quite so orderly as those on the north side. In this case, as in the former, advantage has been taken of the elevation of the Great Central Railway to bring a good deal of the material into the works on a high level, so that it can be fed direct to hoppers, &c. We have mentioned above, for instance, that the north side portable engine testing pits receive their coal from hoppers. These hoppers are fed by an overhead tramway, which starts near the entrance marked "E" on Fig. 3 of the South Side works, and runs along the roof valley of the smiths' shop, across a bridge over Pingle Hill Walk and Station Hill, and so into the engine testing shop at hopper level. This tramway is also made use of to feed sundry other shops, such as the brass shop, smiths' shop, and so on, the handling and hoisting of fuel, &c., being thus obviated as far as possible. The same principle is adopted with regard to foundry and boiler shop work, &c., as in the North Side works. In the South Side shops it will be convenient first to deal with the section concerning itself with thrashing machines, maize shellers, elevators, &c.

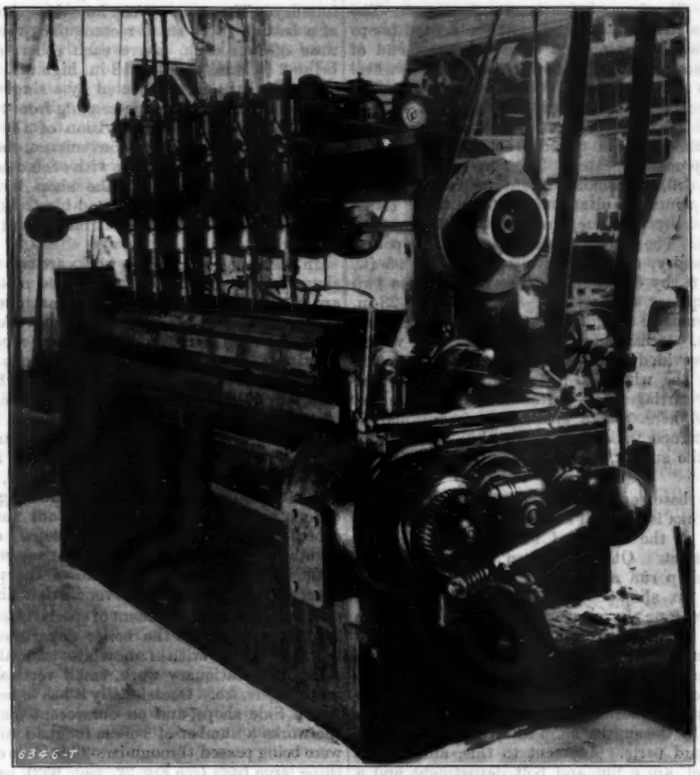


FIG. 19. SIX-SPINDLE AUTOMATIC DRILLING MACHINE.

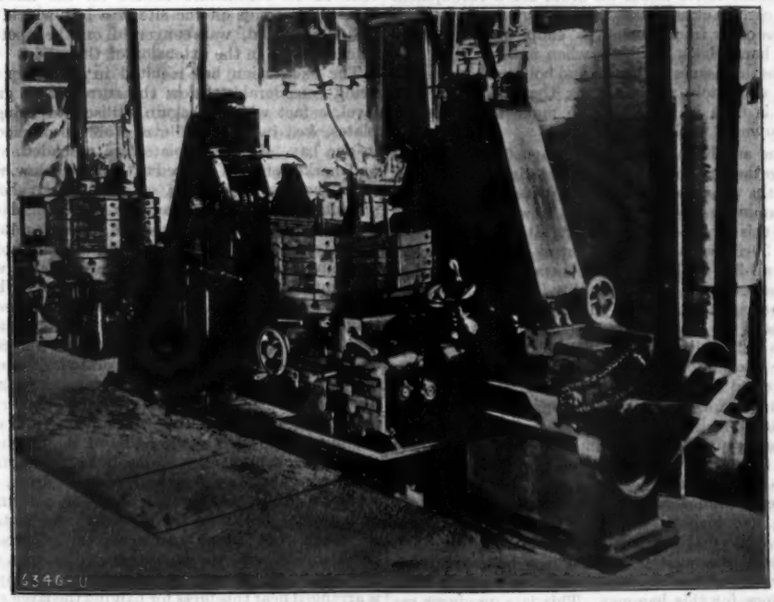


FIG. 20. DOUBLE-HEADED MILLING MACHINE FOR FOUR OPERATIONS.

Close to the entrance of these works, at the top of Pingle Hill Walk, are wood stores, which receive from the Trent Works (dealt with later) stocks of every component required in the woodwork of these machines. Also close to this entrance will be seen in our plan a shop termed the "machine frame shop." This shop draws from the wood store the various wood components and assembles them, drawing at the same time from a general store the small metal fittings required in the process. From this section the assembled parts pass to a long building known as the machine frame store, after being dipped in a large tank containing 12 tons of paint and hung up to drip. The parts in this process are handled by overhead runways. The machine frame store is 310 ft. long by 62 ft. wide. When ready for erecting, the frames from this store are collected into sets, and, with the necessary metal parts from the machinery stores adjoining, are sent up in a large hoist to the erecting shop (Fig. 16, Plate XXXVII). Here the machines are erected. This shop measures 350 ft. by 63 ft. At the south end of this shop the machines are tested, being belt driven by motors placed at about the height of a portable engine pulley, so as to reproduce running conditions as far as possible. Six machines are tested at once. From this shop the machines pass over a bridge to the paint shop, which is 250 ft. long by 60 ft. span, where they are finished off. They are then lowered to an adjoining bay, in which is a long loading line; here they are loaded by electric crane and despatched.

While the woodwork is being assembled the iron work is being proceeded with. It is turned out in the foundry or smiths' shop, as the case may be, and sent into the machine store. It is drawn from here or from a rough casting store under the frame store by the machine shop, which is of two floors on the area in our plan named the machine erecting shop (Fig. 3). Here all the metal work is prepared, machined and fitted, and returned to stores, to be issued, as described above, in sets to the machine frame shop or sent direct to the erecting shop. This store is a three-storied building with a central well. The ground floor is 80 ft. by 48 ft.; the two upper floors extend over a roadway, and are 104 ft. by 49 ft. A two-ton travelling crane is installed. It is heated throughout.

As the South Side shops are devoted to a variety of products less closely related to each other than is the case on the North Side, the routeing appears, perhaps, to be not quite so simple. Actually, the system worked to runs out very well in the shops, which, however, are constantly undergoing transformation as new lines are developed, or one gains some ascendancy over others. The tea machinery, including rollers, firing, sifting and packing machines, is at present being erected partly on the ground floor of the machine shop of the South Side, and partly in the shop at the corner of Colville Terrace and Trinity-street. The latter shop has only lately been taken over for this work, and is not yet completely organised. It consists of three bays, about 51 ft. wide, with one 3-ton and two 8-ton cranes. Several permanent masonry beds embodying pits are being put in here for the erection of these machines. Similar provision is also being made here for the erection of flax-dressing machines, a line in which Messrs. Marshall are preparing for big developments, having acquired the manufacturing rights for the machines of the Fibre Corporation, Limited. The shop formerly devoted to the erection of tea machines, partly used as a machine shop, will be given up wholly in the future to machine tools. The tea machines erected in this latter shop, which is 360 ft. long by 55 ft. wide, have usually been painted and erection-marked here and then dismantled. The parts have been subsequently run through a tunnel leading to a shop under the thrashing machine paint shop already mentioned; here they were packed and hoisted in a lift to the loading floor above.

The machine tool and fitting sections of this shop deal with the metal components for the thrashing and tea machines, and feed the machine stores. Among the tools here may be noticed an auto-

matic six-spindle drill for drilling screen bars for thrashing machines, Fig. 19, page 639. The bars to be drilled are mounted on a horizontal revolving jig, which takes eight bars. The length of the bar is divided equally into six parts, and the drills are set so that each spindle works over one of these sections. On the first set of holes being completed the drills are withdrawn automatically from the holes, and the work is moved on over a predetermined pitch, when another set of holes is drilled, and so on. When the last set of holes to complete the bar is finished, before the drills are again lowered, automatic action causes the revolving jig to turn, so as to bring another bar under the tool, and the drills recommence their function, the work moving in the reverse direction. The attendant has ample time to remove the finished bars and attach others to the jig without stopping the machine. This machine was designed and made in the shops of the firm. The pitch can be varied, the smallest work being $\frac{7}{16}$ in. holes at $\frac{3}{4}$ in. pitch.

Another machine in this shop is a double-headed milling machine also made by Messrs. Marshall. This is illustrated in Fig. 20, page 639. It is designed for dealing with screen and concave bars and drum centres. Two adjustable standards are fitted to one bed with two work tables in front. The drum centres are piled on the front tables as shown, and the faces are machined by end mills mounted on slides on the standards. These work tables revolve to bring the fresh faces in front of the cutter, this movement being obtained by hand-wheel. The vertical feed to the cutter is automatic. The screen bars are piled in carriers on the machine bed, and gang cutters, on the same spindles as the end mills, cut tenons on these bars to standard length. In the same shop are several shoe and shaker crank turning machines, also made by the firm. Each crank is turned on two machines, one doing the main journals and the other the crank journals. The machines are in both cases fitted with standard jigs, so that no time is lost in setting.

Although the wheel foundry (Fig. 17, Plate XXXVII) and wheel shop (Fig. 18, Plate XXXVII) are situated between the two shops last described, it will be as well to return to the high level siding again to follow the material into these shops. Close to the shop marked "Box shop" will be seen two turntables on this siding. The most northerly turns trucks on to a line running through the upper part of a large boiler-house. Coal for the latter is unloaded from the trucks direct into hoppers, to be used in hand or stoker-fired Marshall-Heine water-tube boilers. The material for the wheel-shop also comes over this line, and, after passing through the boiler-house, is turned off along an overhead track which runs to the foundry. Pig and coke for the foundry are thus brought in on a level convenient for charging. Bars for the wheel-shop are also brought in on this level. In the wheel-shop, contiguous to the foundry, the bars for spokes are cut to length, notched and punched. They are then bent to the usual triangular form on a bulldozer, and then transferred to the foundry for the boss to be cast on them, this being done on a special part of the floor shown in our illustration Fig. 17, Plate XXXVII. The spokes are wedged in position on plates on the floor, with blocks round the rim and wedges between the spokes. It has been the practice at these works to cast threads on the wheel-bosses to take the hub-cap; the caps are also cast with the threads on them. Neither the threads on the boss nor on the cap are touched subsequently by any machine. The threads are remarkably clean and a good fit. The centres of the bosses are cast round chill pins. The spoke rivets are then closed by machine. The hoops for the tread of the wheel, received as flat bars, are rolled and welded. A Thompson electric butt-welder has been installed for this work, though some is still done by hand. The electric welder will deal with tyres up to 8 sq. in. sectional area at the rate of 20 to 25 per hour. It is operated with 150-volt alternating current, obtained from a 150-kw. rotary converter run off the 220-volt direct-current shop supply. The rolled hoops are clamped to the machine and the ends brought together. A treadle switch controls the current, which will bring the faces to welding heat in about 30 secs. The ends are brought together by hydraulic pressure. The work is finished by hand. A 6 in. by $\frac{3}{4}$ in. tyre will take about three minutes from start to finish of the welding operation.

The welded hoops are passed to a producer gas-fired furnace, by Messrs. R. and G. Hislop, of Paisley. The floor of this furnace is sloped. The hoops are fed in at the top end, the heated hoops being drawn in succession from the lower end of the furnace and rolled. At the same time a wheel is set on a circular hydraulic table near by. The rolled hoop is passed over it, and the wheel, hoop and table are lowered into a shrinkage pit. When cooled, the table is raised, the wheel removed, and the process repeated. The tyred wheel is then sent to a drilling machine, where the tread is drilled at two points simultaneously. The tread rivets are closed by machine, and the wheel is passed to stores. These two shops, the wheel-shop and wheel-foundry, are respectively 195 ft. by 95 ft., and 165 ft. by 63 ft. span. The foundry has two 4-ton cupolas, sand-mixers, &c., and one 28-in. table pneumatic moulding-machine, as well as hand machines. It has three 3-ton cranes. The wheel-shop is provided with two 3-ton cranes. The store receiving the wheels also accommodates the fore or under-carriages for portables, &c. These are assembled here, and a small department here is also concerned with chimney work. These shops are for the supply, of course, of the North-Side shops.

In the basement under the shops in this part of the works is a metal store for the smiths' shop, which is at the corner of Pingle Hill Walk and Trinity-street. Other bar-iron stores for the smiths' shop run along Trinity-street end of the building on shop-floor level. Above the latter stores are four departments worthy of notice in passing. The first two are a tool-shop and templet store. In the former are made all the die blocks for the smiths' shop, these dies being stored on the same floor, ready for issue to the shops. The templet store contains all sheet and other templets required by the smiths' shop in the manufacture of all standard parts. Adjacent to this, and on the same level, are a nut and bolt department and a nut and bolt store. The latter is fed by the nut and bolt section of the shop below, against demands for recoupments by the main stores; that is to say, the main stores issues an order for a recoupment of a certain class of bolt to these sub-stores. These stores order from the smiths' shop, which complies and hands back the bolts when made. The sub-stores then issues to the nut and bolt machine section and ultimately receives back the finished article, and is then in a position to make the necessary recoupment to the main stores.

The smiths' shop, Fig. 21, page 652, is worked altogether by electric power and air. The smiths' hearths use breeze, but the furnaces are either oil or producer gas-fired. In our view it will be seen that this shop is light and airy. It is of three bays, two 30 ft. wide and one central bay 80 ft. wide, and all 300 ft. long. The central bay is 26 ft. to the eaves. The shop is notably free from smoke or fumes; in fact, is one of the cleanest and healthiest shops of the kind we have been in, although it contains 62 smiths' fires. Formerly the hammers were steam-operated; they have now all been converted to air by substituting Pilkington air cylinders for the original hammers. Some new Pilkington hammers have been added. The hammers number 21, ranging up to one ton. There are further five sets of pneumatically-operated drop stamps, the heaviest of which is 15 cwt. Olivers, bulldozers and other mechanical aids are also in evidence. One corner is devoted to nut and bolt making, the furnaces being oil-fired. Close to the one-ton hammer is a balling furnace for working up the scrap and for heating large forgings for this hammer. This is a producer-gas regenerative furnace fitted with water-cooled valve. It consumes 26 cwt. of coal a day, including firing up, starting at 5.30 a.m. and shutting-down at 5 p.m. During this time 42 blooms of 2 cwt. each are worked up or nearly 4¼ tons of scrap. The case-hardening section is in one corner of the smiths' shop, and has one gas-fired and two coal-fired furnaces.

Close to the smiths' shop is a brass shop where there are floor furnaces for seven 100-lb. pots and two 200-lb., as well as a fixed Tyler furnace for 200 lb. In addition there are two 400-lb. tilting furnaces one Morgan and one Tyler. There are several pneumatic and hand-moulding machines in this foundry. The core-ovens for this shop consist of a battery of 12 small rectangular ovens in three rows of four each, above each other, each oven being 2 ft. 6 in. wide by 18 in. high and 2 ft. 6 in. deep. This battery is heated by a single coke fire, the course of the gases zig-zagging from row to row of the ovens. The sub-division of the oven accommodation is a great convenience, as the men do not interfere in any way with each other's work. The other equipment of the shop includes the necessary mills, rumblers, sand-blast, &c., and an ash-washing machine for reclaiming brass from ash, broken pots, &c.

In the same corner of the works are two tinsmiths' shops, in which wire and perforated metal screens are made for various classes of machines and all the light sheet-metal work is done. An electric spot-welder is here used to replace much of the riveting. A rather ingenious machine is employed in this shop to make elbows on 3-in. to 8-in. pipe. The pipe is placed over a mandrel, which consists of two thick discs with, between them, a thinner disc with a rounded edge. An eccentric movement can be given to the central disc, and when the machine is in use and the pipe set, on being worked this disc causes an eccentric bulge to form on one side of the pipe, running out flush on the other. When the bulge is completed, dies close together on either side of it, and compress it into a fin, which being on one side of the pipe only, causes the latter to curve over in that direction.

The remaining department of special interest in the South Side Works is the boiler department, which normally deals with Lancashire and allied type boilers for stationary work, small verticals, boilers for dredgers, &c. Occasionally it has to help out the North Side shops, and on our recent inspection of the works a number of boilers for road rollers, &c., were being passed through it. This shop consists of three large bays (see Fig. 22, page 652), each 395 ft. long, and has a width of 175 ft. in the centre; a tower bay, 75 ft. in height and 50 ft. wide, runs across the south end of the whole. This bay will take 32 ft. Lancashire boilers on the machines. This shop stands on the site of a hill, which, as it was demolished, was converted on the spot into bricks for use in the extension of the works.

The excavation has resulted in the shop floor being considerably below the surrounding ground level, a fact which is again utilised to bring the plates, &c., into a high level store accommodated in one bay. Here the plates are unloaded, stored and marked off, and lowered to the floor below, where are situated the drilling, punching and shearing machines, rolls, riveters, and so on. On the east side the shop structure embodies a strong retaining wall to support the higher ground. The foot of this retaining work consists of a series of arches which open into the shops and are used for stores for boiler tubes, tube plates, bars, rivets, &c. The overhead travelling cranes in this shop are as follows: one 30-ton, one 25-ton, two 20-ton, one 10-ton, four 8-ton, and two 5-ton, all electrically-operated. There are also numerous wall jib cranes, for carrying the lighter tools, such as pneumatic tapping and drilling machines. One main line of shafting runs down the main bay, with another line of shafting under the stores gallery. In addition to the ordinary machines, such as punches, shears, drills, &c., worked off this shafting, there is a large assortment, of hydraulic machines in this shop; for instance, there are four large presses served by producer gas-fired furnaces, the largest press having a table 12 ft. by 14 ft., and a power of 400 tons. A capstan is arranged near this press for hauling the large plates out of the furnace on to the table. To economise storage space the flanging blocks for these presses are stacked over the furnaces.

In the bay on the west side of this shop are two welding machines for furnace flues, see Fig. 23, page 652. These are on Clark's patent, by Messrs. Mactaggart, Scott and Co. With this machine the rolled flue ready to be welded is placed on a carriage

on a pair of rails in a pit; on another set of light rails, shown entering the flue, is a travelling brick furnace, coke-fired, fitted with an air blast. This furnace is moved into the flue and heats up the edges of the plate, a muffler cover being lowered from a jib crane above on to the upper side of the flue. When at welding heat the fire is withdrawn from the flue, which is traversed on its carriage back between a pair of rollers by hydraulic power. Pressure is exerted hydraulically on the joint, the upper roller being fixed to the piston rod of an hydraulic cylinder. After welding the flue is transferred to a circular fire which heats one end, and when at a suitable heat is placed on a circular flanging machine, Fig. 24, page 652, having been previously lipped at one point. This machine has a revolving table with three rollers above, between which the flange is formed as the work revolves. The flue is mounted on a large horizontal four jaw chuck. On a standard is a heavy slide carrying forming and guide rollers. The principle forming roller is shown inside the flue. It is mounted on a screwed spindle, and as it revolves is worked out away from the flue centre, turning the flange down over an idle roller on the slide. The heel of the flange is finished by a flanged roller behind the former. The side rollers, which act as guides, can be traversed in or out to fit different flue diameters. The whole slide is also adjustable for height so that flues of different diameters and lengths can be accommodated. The machine is belt-driven from the main shafting. It is on Crow's patent, and is constructed by Messrs. Harvey and Co., of Glasgow. Another machine of interest is one of Messrs Marshall's own make. It is intended for jumping the frame or foundation rings of locomotive type fire-boxes prior to bending, so as to secure the extra thickness necessary to retain the section at the corner on bending. The heated bar is inserted between two wedge grips, which close on to it and are then drawn together by hydraulic pressure. The bar is subsequently bent in a hydraulic machine. The hydraulic power supply in this shop is at 1750 lb. pressure. A large accumulator by Messrs. Henry Berry and Co., Ltd., 10 ft. in diameter by 18 ft. high, stands in one corner of the shop. The power is obtained from two 4-throw pumps, belt-driven from a tandem compound engine, which also drives the line shafting of the shop. The boilers, as finished, are filled with water from a hydrant supply, the pressure for testing being obtained by hand pumping.

We have purposely refrained from saying much about the power station at these works, as this is on the point of being abolished. Close to the boiler department, on the South Side there exists a station and boiler house, which will be superfluous on the completion of alterations now in course of being put through. In this station are four 600 h.p. horizontal compound condensing steam-electric sets; two are with rope drive and two are direct-coupled sets. The engines are of the Marshall drop valve type. The adjoining boiler house, now containing eight Marshal-Heine boilers, will likewise be partly abolished. We may state that air pressure is provided in the works at 100 lb. by two steam-driven Pilkington compressors, each of 800 c.f. capacity and one belt-driven Tilghman compressor of 400 c.f. capacity, all of the two-stage pattern. Parallel with the boiler shop, and served by a standard gauge line, is a boiler-mounting bay, where mountings are fitted to all independent boilers, and where they are prepared for loading. There is nothing particular to remark in this connection. The shop is served by a 30-ton crane.

Owing to the hardness of the water of the district, the works have their own water-softening plant, capable of dealing with 600,000 gallons per week, this is on the lime-and-soda system of the United Water Softening Company. In connection with this plant are pumps supplying direct to the works mains, and also to high-level storage tanks of 75,000 gallons capacity, for night working, &c. Additional water obtained from springs on the site is used for purposes not involving heating.

In concluding this more or less detailed description of the Britannia Works, we may say that the general cleanness and tidiness of the shops is quite a striking feature. Although in most places crowded, so that it is necessary to stack the work, and nearly all the floor and yard space is fully occupied, everything is orderly, and there is an absence of the confusion so often found in works whose business has expanded more quickly than their shops. Order and system runs through the whole, and the state of their shops and the rate at which orders are complied with, go to prove that this is a sound policy. Although some of the buildings are now by no means new, for the most part they are light and airy; especially is this the case with the more recent buildings. There is also a distinct absence of fumes and dirt in such places as the smiths' shops. The works are heated with exhaust steam from the main engines, a pump being put on the return-end to draw it through the circulating system, which in some cases traverses very considerable distances. This system is very effective, and maintains the stores, shops, &c., at a very confortable temperature.

(To be continued.)

THE IRON AND STEEL INSTITUTE.

(Continued from page 621.)

IN our last issue we gave an account of the preliminary proceedings at the recent meetings of the Iron and Steel Institute, which were held on Thursday and Friday, the 6th and 7th inst. We now continue our report, the following being a *précis* of the discussions of the papers which were contributed.

IRON PORTLAND CEMENT, WITH A CLASSIFICATION OF CEMENTS MADE FROM BLAST FURNACE SLAG.

The first paper taken was the one having the above title, by Mr. Edwin H. Lewis, Wishaw, who read it in abstract. We reproduced it on page 626 of our last issue. In this, the author reviewed the manufacture and uses of the various cements, and stated that if a certain quantity of properly-granulated slag of the right chemical composition were added to Portland clinker during grinding the strength of the cement could be increased. In Germany it had been agreed that such cement should be sold under the name of "iron Portland cement" provided the quantity of slag added to the clinker did not exceed 30 per cent. of the whole. Nearly all blast-furnace slags could be utilised as raw material for making Portland cement, although in some cases additions of limestone would be required to increase the percentage of lime and reduce that of magnesia, &c. Only some of these slags could be used for the subsequent addition to the clinker necessary for iron Portland cement.

Dr. Desch, who opened the discussion, called attention to the importance of the subject to the blast-furnace industry, in that it opened an outlet for the utilisation of an, otherwise, waste product and yielded a valuable material. The only debatable point was perhaps the addition of 30 per cent. of slag to the clinker. The author's results had shown that he had obtained increased strength in iron Portland cement. He, the speaker, had urged the addition of material of this kind to the clinker, and he explained that by the addition of a material containing silica a combination with the lime took place, yielding increased strength. The action was known to the Romans, who added puzzolana to their product, the puzzolana combined with the free lime, the whole hardening to a rigid, durable mass. This could be done at the present time with a waste product, slag being comparable to puzzolana. Iron Portland cement better resisted the reactions which took place in sea water than ordinary cement, and was an admirable material to use in the construction of docks, sea walls and other works of a similar kind. If iron Portland cement was to become an adjunct of the blast-furnace industry, great care would have to be paid to the quality of the material; formerly, there was a prejudice against the use of slag owing to the presence of sulphides, but that had been overcome, and further improvements could be made when the new industry had firmly established itself. There would result a greater output of cement, and the using of slag for this would mean an advance of great national importance.

Mr. F. W. Harbord, who followed, agreed with the remarks made by Dr. Desch. Blast-furnace slag was in every way equal to other raw materials. The manufacture of cement, however, was a commercial question and, in many instances, the raw materials used were very cheap; in some districts Portland cement could be made as cheaply, using those materials, as in districts where blast-furnace slag was available. The German 30 per cent. slag-diluted cement seemed to give all the results of true Portland cement; another kind having two-thirds of slag meal was of a lower quality.

Mr. A. Hutchinson stated that many years ago his father had patented a process dealing with the manufacture of blast-furnace slag cement, and, in 1880, he had built of that material a jetty at Skinningrove. The material, for hydraulic work, was an ideal one, but objections, so far, had arisen when used for works in the open air. In the Skinningrove jetty one could still distinctly see the marks which had been left on the material by the moulding planks. The matter dealt with in the paper was one of great interest to all blast-furnace owners. In connection with blast-furnace practice there were three particular lines of research open, the obtaining of potash, the utilisation of the slag itself and the turning to account of the heat in that slag. In regard to cement, an important development would be the manufacture of a product which would be satisfactory from every point of view in the open air also.

Mr. Lewis, in replying briefly to the discussion, said Dr. Desch had confirmed practically all he had wished to point out in his paper and had referred to the great advantage of using iron Portland cement in sea water. He (the speaker) entirely agreed with Mr. Harbord in his statement that the manufacture of cement was a commercial proposition. But even if iron Portland cement could be manufactured cheaper than pure Portland cement, all prejudice would not be removed; strong prejudice would yet remain and would have to be dealt with, more especially perhaps as to its use in reinforced concrete. The commercial question, however, was also one to take in consideration and in this connection an important point was the finding and acquiring of land for dumping one's slag. He had not mentioned Mr. Hutchinson's work at Skinningrove for the sake of brevity; that speaker's remarks had confirmed the fact that slag cement had excellent hydraulic properties. The Germans had had their fight, and we in this country had still to have ours with the pure Portland cement makers. In Germany, if the proportion of slag to the clinker was not over 30 per cent., the name was "iron Portland cement"; when it exceeded that amount then the product was called "slag cement." Some such classification would have to be adopted in this country.

BRITISH BLAST-FURNACE PRACTICE.

The second paper described "British Blast-Furnace Practice"; it was contributed by Mr. F. Clements, M. Inst. C.E., M.I. Mech. E., Rotherham. We reproduce it in abstract on page 646 of the present issue.

THE VALUATION OF ORES AND IRON-MAKING MATERIAL.

The third paper described "The Valuation of Ores and Iron-Making Material," contributed by Mr. C. H. Ridsdale, F.I.C., F.C.S., Middlesbrough. We reproduced it in abstract on page 607 of our last issue. In this the author stated that about 10,000,000 tons of pig-iron were made in this country in a normal year, involving the use of about 25,000,000 tons of ore of many kinds, and yet the final decision as to which kinds of ore should be bought was, in most cases, in the hands of men who were not familiar with the running of blast furnaces. As will have been seen from our abstract, the author enlarged upon this vital point, and reviewed the actual working of the blast furnace under its varying aspects, his remarks covering, besides the ore, the different components of a charge and the other factors which intervened. He dealt in detail with the multiple condition which make for the actual practical value of all the iron-making material.

THE CHEMICAL AND THERMAL CONDITIONS IN BLAST-FURNACE PRACTICE.

The fourth paper on the list dealt with "The Chemical and Thermal Conditions in Blast-Furnace

Practice"; it was contributed by Mr. H. E. Wright, Middlesbrough, who read it in abstract. We reproduced it on page 631 *ante*.

In stating that all three papers would be taken together for discussion, Dr. Stead said it was important to note that in spite of all the improvements which had been made in blast-furnace practice, the coke consumption in Cleveland, among other districts, was higher now than before hot blast had been introduced, this being traceable partly to the higher percentage of ash in the coke and also to the mechanical condition of the ore.

Mr. J. H. Wilson, who opened the discussion, and referring to Mr. Clements' paper, said that in the heat balance sheets, the carbon in the carbonates of the charge was included in the heat generated by the combustion of the carbon to CO_2. Granted that this was allowed for on the other side of the balance sheet by the heat absorbed in decomposing this CO_2, he asked whether it would not have given a more correct sheet if this CO_2 had been treated as being inert after leaving the lime. Since this item represented about 13 per cent. of the total heat, its inclusion or exclusion would make some considerable difference in assessing the relative heat values of work done. In regard to Mr. Wright's statement with reference to the replacing of lime by magnesia, he (the speaker) would consider it more correct to assume that magnesia did replace lime in the accepted theoretical proportion. A partial replacement of the lime in a limey slag would lower the fusion point of the slag, with the result that at a similar slag temperature and viscosity at the slag notch, the latter slag would demand an increased proportion of bases. Carried to an extreme limit and totally replacing the lime by magnesia would raise the fusion temperature higher and in a reverse manner demand a decreased proportion of bases in the slag at the notch. The increasing or decreasing the proportion of any compound in a slag must depend chiefly upon its effect on the slag fluidity.

Mr. Henry Crowe asked Mr. Clements whether reciprocating-engine driven blowers—using gas engines or steam engines—were better or worse than turbo blowers.

Professor A. McWilliam, dealing specially with the authors' references to clay with the ore, said that in India in the monsoon months clay was brought down in masses from the mountain sides and adhered to the ore; during those periods ore was not brought in for that reason. He referred also to an individual furnace which he had had rebuilt, the boshes were increased and the output was increased correspondingly with the increased boshes area. With reference to the addition of manganese, he had to settle how much this should be as a standard amount, and he decided to use not more than 1 per cent.; he agreed with Mr. Wright's statement that the effect of manganese upon sulphur was a matter not correctly stated in text books He was glad Mr. Wright had dealt with the subject of alumina and hoped this would be further pushed forward, for a very great difference of opinion existed on this point, some claiming that it was a fairly strong base, whilst others claimed it was absolutely an acid.

Mr. Gerald Cochrane thought that in the design of a furnace suggested by Mr Clements it seemed unnecessary to carry the number of tuyeres up to 16 with all the complications that they involved.

Mr. D. Sillars, dealing with Mr. Ridsdale's paper, said the author would receive the blessing of everyone connected with iron manufacture if his views became common law. The valuation of ores was also to some extent the climax of Mr. Wright's paper. Mr. Ridsdale was not quite just when he said that little attention was paid to the quality of ore which ironmasters purchased, as his tables suggested; no person would purchase ores having 10 per cent., 12 per cent. or 17 per cent. of silica at the same price. Balance sheets could be divided into many parts, and once practical results were obtained the balance sheet could be drawn up rapidly, the matter being one for judgment in ascertaining that the ore offered could be classified with one of which the value was known. Many of the considerations entered into by Mr. Ridsdale were not so very necessary. Dealing with Mr. Wright's statements in regard to heat interception, he (the speaker) said this took place in any furnace conditions, together with many other actions. In the matter of manganese, this, up to a point, was a very helpful ingredient in ores, especially native ores, owing to its action on sulphur. In one of Mr. Wright's tables, the limestone stated as required for ash and sulphur was given as 1½ cwt. and 2 cwt., according to the class of coke used; he (the speaker) thought these figures required revision. The same author had also used the term "available carbon" in the same table, a term which required more explanation than was given. Very little attention was given to the value of material delivered to the ironworks, and he hoped the papers just read would have for effect to help matters in this respect.

Mr. Wilson, Skinningrove, congratulated Mr. Clements on his detailed schedules of furnaces in the United Kingdom. He emphasised the advantage of clearing out siliceous matter from the ore before charging, the using of pure limestone, and added that it was equally important to apply a selecting method for the coke charged in the blast furnace. His firm was adequately washing the coal to remove the shale and other impurities, and this yielded a coke both clean and hard, and with this he hoped to reduce the coke from 25 cwt. to 21 cwt. The coke figure from 1912 had gradually gone up to 25·39 cwt. and 25·69 cwt., owing to the higher ash content. He (the speaker) was associated formerly with Mr. Ridsdale, and the methods the latter outlined he had carried out to a large extent and found them very excellent for the purpose. He was glad to have Mr. Clements' tables, these would be used as standard tables for reference. Blast-furnace fuel, whether in the shape of coking coal or coke, should be standardised and purchased in the same way as foreign ores, to analysis. The blast-furnace manager should, also, carefully clean his own materials.

Mr. E. W. Jackson agreed with Mr. Ridsdale's statement to the effect that it might be bad business to buy a poor ore at a very low price, and a good business to buy a better ore at what appeared to be a very high price, but the converse was true also, and it might prove quite a sound business transaction to buy a poor ore at a cheap price. Mr. Ridsdale had also said that if the sulphur was present as sulphate in combination with lime, it was far less liable to be decomposed; he (the speaker) questioned the author as to the presence in this connection of sulphur as sulphate. He would also like to have more particulars as to the ironstone referred to by Mr. Ridsdale in table form, in three degrees of cleanliness, showing the increase in limestone needed with the increase in silica, and to know, for instance, whether this was Cleveland ironstone. If it was Cleveland ironstone, the alumina was low, in one case, at 6·14 per cent. Taking the third column, applying to that stated as "bad," it was hard to believe that this had come from the same mine as the material in the two other columns. The ore, calcined, in Mr. Ridsdale's third column was 54·2 cwt., this could be taken in conjunction with Mr. Wright's coke figures for mine qualities, one of which had 54 cwt. of mine per ton of pig-iron, Mr. Ridsdale's coke consumption being 35·42 cwt., whilst the figures of Mr. Wright were: Carbon, 21·59 cwt.; coke A, 27·87 cwt.; and coke B, 31·03 cwt. He (the speaker) would like to have an explanation of the discrepancy. The carbon monoxide did not appear able to reduce the oxides of iron completely, and he would ask Mr. Ridsdale whether it would be possible to add carbon monoxide and hydrogen in the high regions of the furnace.

Mr. H. Scott found that the tendency to-day was to attack the fuel producers; it might be that the ironstone producers were also deserving of criticism, as it was hard to understand how any iron at all could be obtained from some of the deliveries of stone. The authors had said it was desirable to prepare the ironstone; the question of size played a great part, and he (the speaker) was interested in Mr. Clements' statements regarding the possibility of having recourse to sintering of the fines to render them more readily acceptable in the furnace. In the Midlands, for the calcining of green stone, kilns had been put up, and the ordinary, natural blast not proving satisfactory, forced blast was used, when good calcined material was obtained. There was, however, about 50 per cent. in a fine state of division; the material was more friable than the Cleveland ironstone. The question of utilising the green carbonates in question would have to be considered in the future. According to Mr. Clements', his sintering was a complete success; he asked whether his material was brown or green carbonates.

Mr. Clements, in the course of a brief reply, congratulated Mr. J. H. Wilson for having noted the point referred to in his remarks; he (the speaker) added that one could not really tell what happened to the CO_2. For supplying the blast, reciprocating engines were preferable to turbo-blowers. He was very glad to obtain from Mr. McWilliam confirmation of some of the points covered by the paper, and to see, from Mr. Wilson's remarks, that special efforts were being made to improve the coke. In reply to Mr. Scott, the ore he had dealt with was brown ore and not green ore. He added he would reply by writing to all other points.

DINNER AND EXHIBITION.

At the dinner which took place at the Connaught Rooms after Thursday's meeting, and at which some 450 members and friends sat down, Sir Robert Horne, President of the Board of Trade, proposed the toast of the Institute, congratulating the members on the evidences of renewed development on the part of firms engaged in the industry. This toast was responded to by the president, who told his audience that the Council of the Institute had determined on a policy of progress, and instead of shelving some of the numerous papers submitted, had arranged for an adjourned meeting at Sheffield for their consideration. In addition, winter meetings were to take place and a method devised by which the members would be able to nominate and elect their council. After the dinner an interesting innovation was introduced in the shape of a series of moving pictures illustrating various methods of steel-making at the Breuil Works of Messrs. Schneider, at the Brown-Firth Research Laboratories, Sheffield, and at the plate mill of Messrs. Dorman, Long and Co., Limited, Redcar; there was also shown a series of pictures recording the effect of strain on the structure of metal undergoing tests, and other illustrations of metallography by Dr. W. Rosenhain. Besides these pictures a most interesting collection of exhibits had been gathered together in rooms adjoining the dining hall, and included amongst them were some beautifully-finished wax models by Mr. Harry Brearley illustrating the structure of steel ingots, telemicroscopes for the examination of cast-iron fractures exhibited by Mr. E. Adamson, hardness testing machines by Dr. W. H. Hatfield, Mr. Harry Brearley and Mr. R. M. Leslie; a depth indicator for measuring hardness test imprints by Mr. T. J. Primrose, the neat autographic notched-bar testing machine by Mr. J. C. W. Humfrey, very excellent photo-micrographs of coal sections, by Mr. A. C. Booth, with suggestions as to the uses for coals showing different structures; and a beautiful fir-tree crystal of steel (19 in. long) by Mr. J. S. G. Primrose. The British Thomson-Houston exhibited specimens of their thermostatic metal for indicating variations of moderate temperatures; application of the material to devices for the indication of the temperatures of liquids or of ovens showed the temperatures by means of connections to pointers in front of dials. In one room was grouped together an excellent collection of apparatus for the demonstration of X-rays and their application to the examination of iron and steel, whilst radiographs of metal and of other materials were sent from Woolwich Arsenal under the care of Dr. V. E. Pullin. There were also some very informative radiographs of welds in ½-in. steel plates and illustrations of flaws, defects, &c., in various materials by other exhibitors.

At Friday's meeting, Dr. Stead proposed, and Professor McWilliam seconded a vote of thanks to all those who had so ably contributed to make the above display a success; the vote was carried by acclamation

BLAST FURNACES.

On the members reassembling on Friday morning, the 7th inst., Mr. Ridsdale replied to the discussion

on his paper, and, dealing with Mr. Sillars' remarks, said that the ores he had classified as good, normal and bad in his tables were from the same mine and had been delivered to the blast furnace over a period; there was nothing extraordinary in the occurrence. With reference to the presence of manganese, one of the points for this was to make the furnace drive and the getting of a cutting slag. With reference to the remarks by Mr. Wilson, of Skinningrove, the cleaning methods he had referred to formed the direction in which to work. In regard to purer coal he (the speaker) sampled coal quite apart from the analysis, and found that the purer coal ran from 3 per cent. to 5 per cent. of ash, the higher ash being due to included shale. Mr. Jackson had said it might pay to use cheap ore; that was true if the gangue were limey, as it would lead to a saving in limestone. With reference to the presence of sulphur as sulphate, this was not so bad if it was tenaciously held by the lime. If pyrites there was molten sulphide of iron. In regard to the amount of clay in the stone, Mr. Wright had given figures of reduction and he (the speaker) had emphasised the point at former meetings of the Institute. It was evident that standardisation had to be introduced in blast-furnace practice; from the point of view of fuel alone, there was more coal, in the shape of coke, used to-day than formerly to make a ton of iron, and if some percentage of this could be saved it would enable us, among other considerations, to help France and Italy where fuel was badly needed. Further, masters and men should work in this, as in other branches, unselfishly.

Dr. Stead here added a remark concerning the presence of sulphates or sulphides in the ore and said their action depended upon their association in the ore and the amount of silica also present. In crucible experiments if enough silica were present to take the base, the sulphur went into the iron. When the temperature in the furnace fell the sulphur ran up in the iron at a quick rate. There was a greater tendency for the sulphide than the sulphate to go into the iron.

Mr. Wright was surprised that there had not been more criticism of his paper, for it covered practically the whole of the blast-furnace theory, and this afforded him satisfaction. Mr. J. H. Wilson had spoken on the effect of magnesia in increasing the fluid slag; he was right in this to some extent, but he (the speaker) did not find that magnesia did replace lime as it should do in reference to atomic weight combination. It gave some benefit, but one could not in actual practice replace lime by magnesia in proportion to the atomic weights of 1 to 1·4. In his (the speaker's) experience it was practically impossible to conceive that aluminia could act as an acid; it involved such an amount of lime that the slag would be too thick to work. It was introduced in the furnace in the form of clay or siliceous alumina. In the action of lime as compared with that of alumina, Mr. Ridsdale took the same view as he. Mr. Sillars had raised objection to his method with reference to the heat units and to that followed in dealing with the fusibility of iron in CO and CO_2. In blast-furnace practice it was usual to work in hundredweights, and one was fortunate when one could weigh within 1 cwt. His (the speaker's) method appealed to the ordinary man employed in blast-furnace work, and the object of the paper was stated in its first three lines; it did not apply simply to persons who were most learned in the subject. But with reference to the heat units theory he had an open mind; the unit used did not matter so much, as following up the process right through per unit adopted. Mr. Sillars preferred to go in modern theory by using diagrams, and in this connection he (the speaker) referred to the figures given in the paper of his experiments in a retort with six different mines and ores, showing the percentage of oxygen removed in the case of each; but in actual blast-furnace practice the grades of the fuel came in and actual conditions could not be brought into laboratory experiments. He did not consider the 1 per cent. of manganese was justifiable in pig-iron. If the iron produced were used for steel one could get on without the 1 per cent loss. As to the 1¼ cwt. and 2 cwt. of limestone required, in one instance quoted, for ash and sulphur, he had purposely kept the figures low not to overstate the case. In regard to the term "available carbon" he had shown how that was made up in his table IV and in the data at another part of his paper.

Direct Current Compared with Three-Phase Current for Driving Steel Works Plant.

The first paper taken on Friday, the 7th inst., was the one by Mr. C. A. Ablett, M.I.C.E., on "Direct Current Compared with Three-Phase Current for Driving Steel Works Plant." It was read in abstract by the author, and we reproduce it in the present issue. The paper dealt with the electric driving of merchant and bar mills, sheet and tinplate mills, other rolling mills including reversing mills, and with the driving of the live roller gear, the author showing that under many conditions it was advantageous that direct current be adopted as the system of supply of a steel works. Dealing with the current supply, he said it would appear better for a works having blast-furnace gas, coke-oven gas, or other natural sources of power, to instal their own standby plant, rather than contract with a power supply authority to provide a standby. If they put down their own plant and charged themselves annually a similar sum to that they would be paying an outside authority, the cost of the plant would soon be paid off. By relying on the outside authority, the annual charge went on perpetually.

Mr. F. P. Clarke, who opened the discussion, said the author had dealt with the subject in a very compact and sound way. He had confirmed most of his (the speaker's) views. That was perhaps the case more especially in regard to auxiliaries. Some establishments had put down three-phase machines for driving the live rollers, others had used direct current, and many of the former had had ultimately to replace their 40-h.p. three-phase motors for this work by 20-h.p. direct current ones for the same duty. He asked whether it was possible to transform alternating into direct-current without the use of a rotary converter; was it possible to cut out this expensive piece of machinery without an attendant loss of energy? He noted that a turbo-alternator was less high in capital cost than a turbo direct-current generator; and for long distances three-phase was easier to handle. If, therefore, three-phase could be converted into direct current without the use of a rotary and its attendant expenses there would be but little alternating current used in steel works. He also completely endorsed the author's views in the matter of the linking up with outside power companies. These latter had power to spare at the week ends, and that was the time when the steel works did not require it.

Mr. W. Dixon found that the author's paper had some similarity from the economic point of view with the one by Mr. Ridsdale, and thought that a great part of the trouble which had been experienced with electric drives was traceable to the fact that in the early days the electricians were not engineers also. He feared that the Government schemes now being promoted would result in the country being flooded with alternating current, that was to say, with the least suitable form of current.

Mr. H. Crowe was in the same position as Mr. Clarke. He had acquired a large experience in the use of electricity in steel works, the works with which he was connected having been among the early ones to adopt electric-driven mills. He agreed with the author in all he said. It was the correct thing to do to couple up works having blast furnaces to others having rolling mills. The author was also right to state that in a three-phase motor, when the load was varied, there was a loss of power, unless the motor was complicated and costly, and not well suited to steel works' purposes. A saw, for example, could be driven by a 40-h.p. direct-current motor, but would require a three-phase motor of 60 h.p. and more. There had been too many cases in which alternating current was used because that was the form of current available in the supply. The contactor gear generally used worked more satisfactorily with direct than with alternating current. In direct-current motors commutation was now so good that there need be no fear of commutation trouble. In the sudden reversal of any gear, three-phase punished the machine very much more than direct current. In a direct-current crane, the lighter the load hoisted the lesser was the load on the motor. All the drives in his works were by direct-current motors, and he doubted whether it could be possible to use in their stead alternating-current motors of any sort. The author had referred to the swinging of the flywheel in one instance he stated; he (the speaker) had a machine coupled to a slow-speed gas engine which worked well. In the matter of coupling up with a power supply, if a number of gas-engine driven machines can be made to run in parallel with each other, why, he asked, could they not be made to run in parallel with a steam turbine driven one. This would be preferable to coupling-up with an outside power supply.

Mr. D. Selby-Bigge mentioned the numerous papers which he had read before the Institute on the utilisation of electric current in steel works, the last one being in 1910. Mr. Ablett was now continuing the work, and he (the speaker) found his comparisons accurate and most evenly balanced as between alternating current and direct current. The author had said that direct current did not lend itself to cheap transmission of power over long distances; this was correct for ordinary direct current, but there was another form of direct current in other countries, the high-tension direct current or Thury system. He had applied it for the first time some years ago to motors for winding at coal mines in Scotland and in Spain, with complete success. In the matter of speed variation there was no trouble after nine years' constant operation. The author was correct in his conclusions in relation to outside power supplies and steel works having assets of their own; he (the speaker) had always thought it was better for the works to utilise that power themselves than to deal concerning it with supply companies. The power companies came in when the question was one of the purchase of relatively small amounts of current, but when it was one of thousands of horse-power, it would pay the works in almost all cases to produce their own power on a large scale.

Mr. W. F. Beardshaw agreed with the last speaker. The author said the statement had been made that it was cheaper to drive hot sheet mills by steam than electricity, and believed there was a foundation for that statement. He (the speaker) said they had mills in Sheffield which they were satisfied were cheaper to run by town power than by steam.

Mr. A. Hutchinson congratulated the author on his contribution. Most of the members were convinced that the electric drive had come to stay, and it was very useful now to have the information the paper conveyed. The author was able to give that information, for he was engaged on the work at its very inception. Three-phase current had been adopted at first partly for the reason that the outside power sources provided the best means to meet an eventual stoppage. But it was right for steel works to avoid the outside supply authorities; there was no excuse for it now. Works should link up together with the blast furnaces until all the waste gas was utilised, and at the week ends a means should be devised for extracting nitrates from air, with the power available at those times.

Mr. A. Lamberton found that the paper came at a time when one was looking for confirmation on several points. He was rather surprised to find that there had been no one to defend alternating current. The author was the pioneer of electric rolling-mill drive, and he was well qualified to deal with the subject, many members would look to him for further guidance. He (the speaker) had had the opportunity a few days before of discussing the question of rolling mill motors with an American engineer who was entirely in favour of alternating current for the purpose; he thought that engineer would be present at the meeting, but had heard since that he had another engagement.

Mr. E. Crowe said that in his experience also there was no question of the superiority of direct current over alternating in steel works, particularly as to speed variation and reversal. It was essential in a machine which was required to be promptly brought to rest. As to the statement that steam

drive was cheaper than electric for hot sheet mill running, that depended upon the price paid for current, and if current was derived from waste heat the electric drive was cheaper. It was not cheaper if the current was bought from the outside.

Mr. Ablett, in the course of a brief reply, thanked the meeting for the way in which his paper had been received. No one connected with power supply authorities had been present to discuss the question of linking up with them, and it could be taken that these authorities also agreed with that point. In the matter of the cheaper conversion of three-phase into direct current, he hoped there might soon be seen a development in this direction also, which would be commercially good. If it was wished to run machines in parallel situated a distance apart, it was necessary that the dimensioning of the line and the connections be correct, the resistance had, also, not to be too high. It was advantageous to the works to link up together and not with a third party. The week-end power was a valuable asset to the works and should not be allowed to go to waste. The field to be covered was a very wide one; he did not want to enlarge his paper too much, but hoped to deal with other points in the near future.

Notes on Slag Conditions in Open-Hearth Basic Steel-Making Practice.

The second paper, taken on the 7th inst., dealt with "Slag Conditions in Open-Hearth Basic Steel-Making Practice," by Mr. J. F. Wilson, Frodingham, who read it in abstract. It described the action which the slag played in basic open-hearth steel manufacture, the subject of slag composition being dealt with under three separate headings—silicate, phosphate and tapping slags—the composition and the part played by each being entered into in detail. We reproduce the paper on page 661.

The Reduction of Silicon from the Slag in the Acid Open-Hearth Process.

The next paper had the above title and was contributed by Mr. B. Yaneske and Mr. G. A. Wood, Sheffield. We reproduce it on page 666. It opened by stating that frequently the percentage of silicon in acid steel was much higher than required, although the same weights of finishing materials had been added which normally yielded the desired amount of silicon. This pointed to the fact that there must have been more than the usual amount of residual silicon in the metal, and that either this element had never been satisfactorily eliminated during the working of the charge, or that after being eliminated it had passed back into the metal as the result of reduction from the slag. The authors reviewed the conditions which obtained in a number of charges and followed up the working in detail.

The discussion on the two papers was opened by Professor McWilliam, who stated that as he had been engaged for the last seven years in steel-making on the basic process he could congratulate the author of the first paper. He, also, welcomed the bringing in together the results of further experiments in the acid and the basic open-hearth furnaces. One point he had always insisted upon was to the effect that the reduction of the silicon in the steel was governed by the composition of the slag, the temperature being subsidiary. It was satisfactory to find that younger workers had confirmed that point. All his (the speaker's) further work had supported that former view of his. The authors of the second paper had stated that in the two heats by himself (the speaker) and Dr. Hatfield, made in 1902, there was no proof that the reduction of the silicon was effected by the carbon; he thought the authors had made a strong case for the reduction by the iron. He still held that the high silicon Bessemer blow would really be the condition under which to obtain a high siliceous slag.

Dr. Hatfield joined Professor McWilliam in complimenting Messrs. Yaneske and Wood for the firm stand they had taken on the theoretical side of the matter. He (the speaker) agreed with them in weighing out the silicon going to the metal and the carbon going out, and thought that their suggestion of the reaction which took place was a plausible one. It had not yet been demonstrated in actual practice; the experiment could be done in a laboratory working at high temperatures, and a confirmation of their suggestion arrived at. At the time of his (the speaker's) and Professor McWilliam's heats referred to, physical chemistry could not be said to have been applied to furnace operations, and this was becoming more and more important. Another problem awaited solution; if tapping samples were taken through the charge, the carbon content hung up and then suddenly fell down. An explanation was wanting for that. It might be that changes in composition and temperature were facilitating the reduction of iron. With reference to Mr. Wilson's paper, he objected to a statement to the effect that iron oxide relative to lime could act as an acid, and in steel furnace could act as such at comparatively low furnace temperatures. He did not think that was an actual fact, and suggested there was no evidence of the important chemical action which was there advanced.

Mr. J. H. Whiteley, dealing specially with Mr. Wilson's paper, said all members admitted that the subject was one as to which we were still in ignorance; a large amount of work had been carried out, the net result of which was to leave us practically where we were. He took exception to the author remarking that it was inaccurate to say that a certain slag, after allowing so much of its various constituents for fluxing, contained so much "free" acid or "free" base, and thought he had put himself here to unnecessary trouble, since later in his paper he had referred to excess bases and acids, and to their action. There were three possible ways in which the iron content of the slag could increase, by iron oxides from the metal to the slag, but not in the basic process; then by the action of metallic globules in the slag forming ferrous oxide; there was further the reaction between ferric oxide and the iron itself—as he explained by a number of formulas on the blackboard, pointing out the difference of the actions in the basic and acid processes.

Mr. E. H. Saniter stated he had not had time yet to consider both papers in detail; both suggested many new things and deserved full attention. Mr. Yaneske's paper had rather disturbed his (the speaker's) views on the subject and he could not see how free oxygen could go through the sample shown and perforate it. The question of silicon reduction by iron and possibly iron and carbon was due to the high temperature in the open-hearth furnace. If the iron reduced silica to silicon, the iron would be in a state to absorb FeO. In regard to Mr. Wilson's paper, it was undesirable to talk of viscosity in regard to slag; the terms thick or thin slag should be used. In the author's table III he was surprised at the various amounts of calcium sulphate shown by the slags; it must have been there as sulphide of calcium. There had been a component separated by Dr. Stead as ferrite of lime. With reference to Mr. Whiteley's remarks as to the difference in the action in basic and in acid furnaces, one could work so as to have any amount of Fe in the slag; the question was entirely one of working the furnace. With a neutral slag one did not get a rise of iron in the slag. If one worked with an extra basic slag, say up to 50 per cent., one would require a truck load of lime because the oxide of iron was coming from the bath to the side so rapidly. It was the composition of the metallic bath which governed the composition of the slag.

After a few remarks by Mr. Bainbridge concerning several assumptions in Mr. Wilson's paper, which he (the speaker) stated represented occurrences in the converter process and not in the open-hearth furnace, Mr. Hallimond stated he was particularly interested in Mr. Wilson's paper. The silicates in basic slag were very complex and there was still a large amount of work on the subject for those who could spare the time. The author's division of slags into the olivine and the mellilite types was one really due to Vogt. He (the speaker) had been much interested in the slags produced by Mr. Wilson, and asked whether the latter could spare some samples for the Museum in Jermyn-street. He also dealt with the formation of slag in the furnace, its action and composition.

Dr. Stead said he had never disagreed with Messrs. McWilliam and Hatfield (this in reference to a statement in the paper by Messrs. Yaneske and Wood). He knew that if white iron were treated in a silica crucible probably at its melting point one might keep it there a long time without reducing the silica. If it were heated by the electric arc, one could get all the carbon out and replaced by silica from the crucible. This was the basis on which ferrous alloys were made. He did not say the silica did not react upon iron. He had treated metallic iron with phosphoric acid and had obtained 5 per cent. of phosphorus in the alloy; the iron took oxygen from the phosphoric acid and there was obtained oxide of iron. He had also taken a most siliceous open-hearth slag, he had added 10 per cent. extra silicate to it, put it in a silicate crucible, heated it to 1,650 deg., and had obtained a beautiful button in the crucible, but no silicon in the iron. He did not say that iron did not reduce silica if sufficient time were given it.

Mr. J. H. Wilson, dealing with the paper by Messrs. Yaneske and Wood, said in regard to free bases and free acids he would consider the matter from the point of view of the highly acid slag. The authors had said it could occur that the slag became so siliceous that it contained more silica than was required to combine with the basic oxides in the slag to preserve an equilibrium. From their definition it was reasonable to say that the slag had reached the degree of solidification where saturation with silica had its fullest extent. He (the speaker) was inclined to go a little further and to suggest it was the point where the slag composition was equal in degree of solidification to the most siliceous mineral that could be produced in the furnace and that this mineral was probably tri-silicate. Vogt had noted the presence of globulites and crystallites in highly acid slag, approximating to tri-silicate; this could be taken as an indication that tri-silicates could be formed. In regard to the reduction of different compounds from the metal into the slag and from the slag into the metal, he would say, that he had come to the conclusion that the thermo-chemical constant had a great deal to do with it. A compound which was oxidised from the metal would be oxidised in the order of its thermo-chemical constant in the same way as a compound was reduced from the slag into the metal would be reduced in the reversed order of its thermo-chemical constant.

(To be continued.)

LIQUID-FUEL-FIRED STEAM MOTOR WAGON.

An interesting application of liquid fuel firing to a steam motor wagon is illustrated on the opposite page. The wagon concerned is a 3-ton "Sentinel" in use by the Liverpool Fire Brigade. It was converted to liquid-fuel-firing on their pressure-jet system by Messrs. Kermode's, Limited, of 35, The Temple, Dale-street, Liverpool. As will be gathered from Figs. 1 and 2, the installation of the liquid fuel arrangements proved a comparatively simple matter. A hand pump, shown at A, in Fig. 1, was installed, to pump air into the oil tank above the oil and so create the head necessary for the pressure-jet burner. In the Kermode burner oil under pressure enters at the side and travels forward in an annular space formed between inner and outer cylinders. At the end of the annular passage there is a cap with grooves through which the oil passes to a central opening through which it is discharged. This opening is controlled by a conically-ended spindle which passes through the inner cylindrical part.

The various fittings necessary for the installation are indicated in Figs. 1 and 2. As we have already said A is the hand pump for supplying pressure and, of the remaining letters, B refers to the relief valve on the oil tank and C to the filling plug. A control valve with its operating lever are shown at E and F, and a shut-off cock at K. The fitting at H is a pressure gauge, D is an oil filter, and G the burner. Details of the "Sentinel" boiler are shown in Figs. 3 to 5, with the position of the pressure-jet burner indicated. The oil used on this wagon requires no pre-heating. In the case of a similar wagon fitted to burn crude petroleum a combined steam and hand pump lifts oil from a bunker tank and delivers it through a heater and filter to the burner. Other details are much as in the example we illustrate. In both installations in the event of the wagon having to stop, the major portion of the oil is cut-off by operating the valve E, but enough passes to keep the burner alight, the state of affairs corresponding to that of a banked fire. To start again the valve is fully opened. We understand that there is no trouble with smoke at either end of this operation.

LIQUID-FUEL-FIRING APPLIED TO A "SENTINEL" STEAM WAGON.

MESSRS. KERMODE'S LIMITED, ENGINEERS, LIVERPOOL.

(*For Description, see opposite Page.*)

Fig. 1.

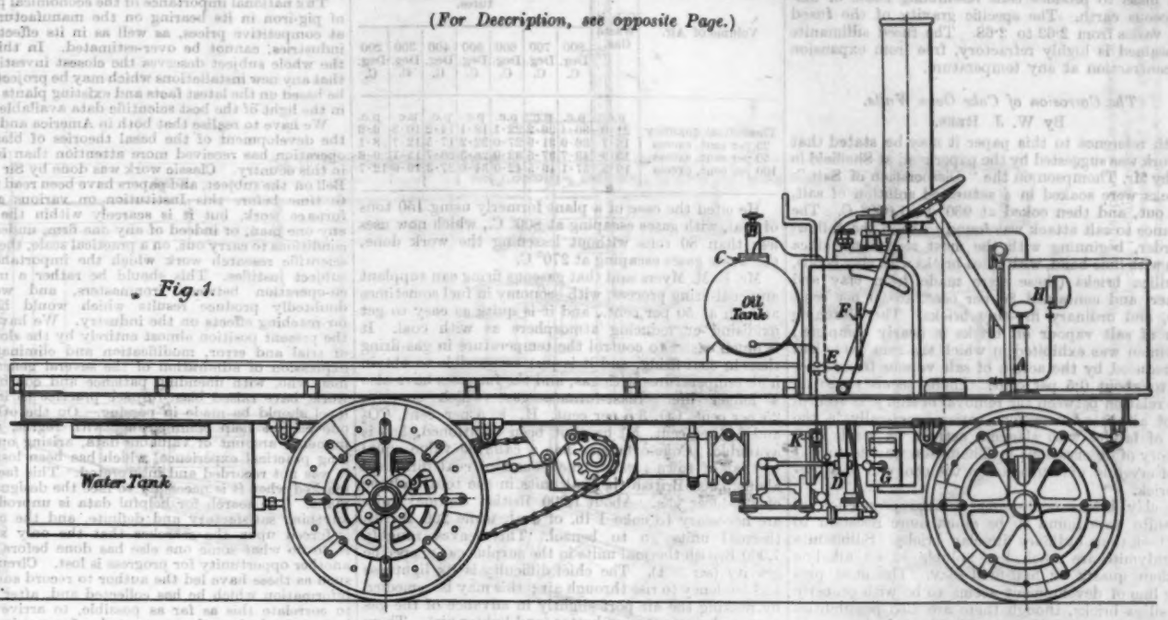


Fig. 2.

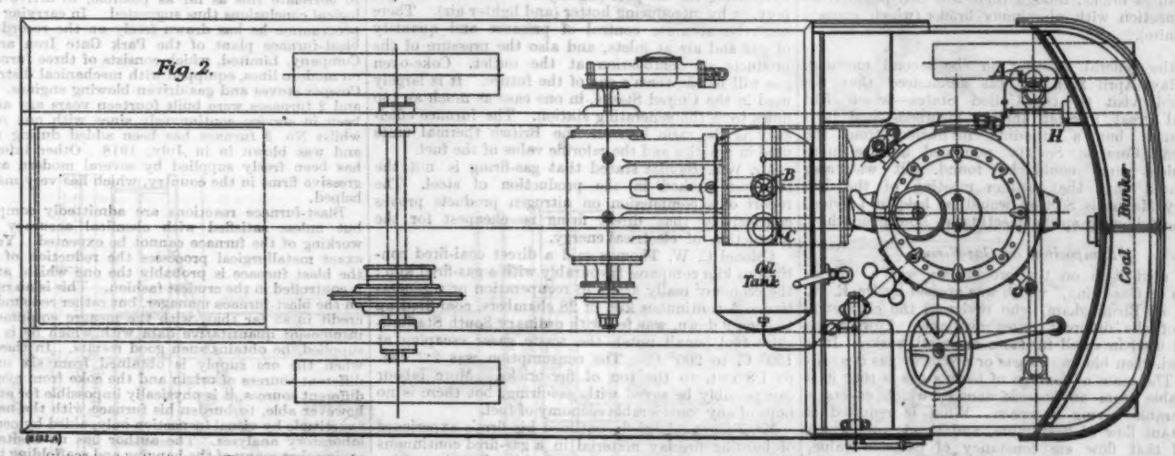


Fig. 3.

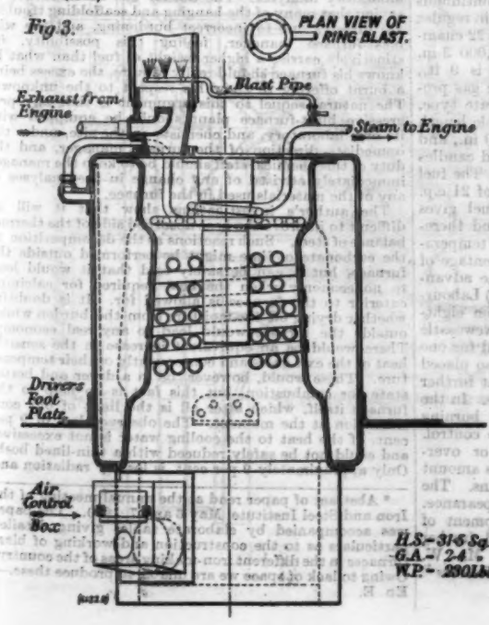


Fig. 4.

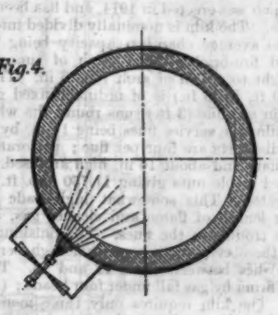
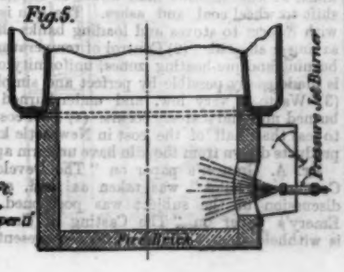


Fig. 5.



THE CERAMIC SOCIETY.

(*Concluded from page 611.*)

We now continue our abstracts of papers read at the meeting of this society on the 29th ult.

Fused Artificial Sillimanite.

By A. MALINOVSKY.

In this paper the following are the main points. In the case of single oxides the most stable refractory products are apparently obtained in the crystalline state, as tridymite and cristobalite for silica, periclase for magnesia, and alundum for alumina; these give a dense refractory with a constant volume when used under furnace temperatures. The conversion of silica into tridymite and cristobalite, and of magnesia into periclase is very sluggish, though fine-grinding hastens the conversion. Similar considerations apply to double oxides such as sillimanite (Al_2SiO_5) and spinel ($MgAl_2O_4$), but it is difficult to bring about proper combination, which does not seem to take place short of fusion.

The author has devised a new process for bringing about such fusion with formation of sillimanite crystals. Crushed aluminous rocks or mineral are smelted in a special cupola furnace along with carbon (in the form of coke or other carbonaceous material). It is possible to regulate the volatilisation of the silica by making the amount of reducing agent enough to reduce all or only part of the silica, leaving only part of the silica unreduced so as to convert all the charge into sillimanite or only part of it. The aluminium and silicon (of clay, for example) are first converted into carbides —carbon dioxide passing off—and afterwards into sillimanite and silica, with more carbon dioxide. The

volatilised silica has a specific gravity of 0·11747, and is snow-white. To bring the whole charge to boiling takes from five hours to six hours, and the cooling one hour. Air is blown (at 5 lbs. pressure) into the fused mass to produce cells resembling those of diatomaceous earth. The specific gravity of the fused mass varies from 2·62 to 2·68. The fused sillimanite so obtained is highly refractory, free from expansion and contraction at any temperature.

The Corrosion of Coke Oven Walls.

By W. J. REES.

With reference to this paper it may be stated that the work was suggested by the paper read at Sheffield in 1918 by Mr. Thompson on the "Dissociation of Salt."

Bricks were soaked in a saturated solution of salt, dried out, and then coked at 950° to 1,000° C. The resistance to salt attack was found to be in the following order, beginning with the most resistant: silica bricks with lime bond, with silica bricks with clay bonds, semi-silica bricks (these were made from clay and ganister, and contained 80 per cent. to 90 per cent. silica), and ordinary fire-clay bricks. The bleaching action of salt vapour on bricks is nearly complete; a specimen was exhibited in which the iron oxide had been reduced by the action of salt vapour from 3 per cent. to about 0·5 per cent. There seems to be no direct relation between the removal of iron and absorption of alkali. Absorption varies practically in the order of failure with slagging action. A result confirmatory of observations by Thompson was the formation of crystals of hematite on the cool end of a fire-clay brick.

Fire-clay bricks containing a large proportion of sillimanite were found to be much more resistant to salt attack than ordinary fire-clay bricks. Sillimanite and tridymite are much less soluble in an alkaline flux than quartz or half-fired clay. The most promising line of development seems to be with properly made silica bricks, though there are also possibilities in connection with aluminous bricks (which contain sillimanite).

At the general meeting on the second morning, Thursday, April 29th, it was announced that the proposed visit to the United States—which had aroused great interest among members—had been postponed, but a standing invitation from the American Ceramic Society remained until a more convenient time could be found. It was also announced that the autumn meeting of the Refractory Materials Section would be held in London, and the following spring meeting at Bournemouth.

Symposium on Gas-Firing.

The next item on the programme was a "Symposium on Gas-firing," which was opened by Dr. E. W. Smith, of Birmingham, who reviewed the characteristics of the different gases available. Town's gas is only used in small furnaces or small works. It is not used when blue water gas or producer gas is available. The main advantage of town's gas is that it is obtainable from an outside source, which effects a considerable saving in space. What is required is a constant flow of heat units, and the factors which control that flow are constancy of calorific value, constancy of pressure, and constancy of specific gravity, this last being of supreme importance. Absolute constancy of conditions is not always necessary in the case of large operations. But the high cost of production of heat units is against town's gas. The adoption of vertical retorts reduces the cost of gas, even after allowing for the lower calorific value. Up to 1,500° C. or 1,600° C., inerts are not of importance if constant—even if high. Blue water gas costs more than coal gas, owing to the demand for coke. With a holder there is great regularity of results, but confined to the use of coke. If steam is producible economically at the works, all the better. The relative cost of producer gas, coal, and blue water gas is 3, 4 and 5 respectively, on a British thermal unit basis. So producer gas (cold) is much the cheaper form of gas on this basis, and almost any combustible can be used with it if of reasonably constant quality. Durham coal—even a bad Durham coal—can be used with producer gas, but not if mixed with other coals. Whether with external generators or internal producers, any type of fuel can be used, if the conditions necessary for that type be studied. Steam should always be used in all producers, if only to cut down clinkering troubles. If coal be used in producers, recovery plants should be adopted. Very few coke ovens have facilities for disposing of their surplus gas. It is not always practicable to put in producers. Gas from complete gasification of coal may be used. These plants are as easy to operate as blue water gas plants, and either coke or coal (caking or non-caking) may be used.

Mr. H. M. Ridge called attention to the necessity of regulating the supply of fuel (gas), as well as of air. In many cases air is admitted vastly in excess of the amount required. He gave the following table showing the heat lost under various conditions:—

Volume of Air.	CO_2 in Waste Gas.	Total Heat left in Waste Gas at Different Chimney Temperatures.						
		800 Deg. C.	700 Deg. C.	600 Deg. C.	500 Deg. C.	400 Deg. C.	300 Deg. C.	200 Deg. C.
	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.	p.c.
Theoretical quantity	21·0	30·4	26·2	22·1	18·1	14·2	10·3	6·6
25 per cent. excess	16·7	36·9	31·9	27·0	22·2	17·5	12·7	8·1
50 per cent. excess	13·9	43·7	37·8	32·0	26·3	20·7	15·1	9·6
100 per cent. excess	10·5	57·1	49·5	42·0	34·6	27·3	19·9	12·7

He cited the case of a plant formerly using 150 tons of coal, with gases escaping at 800° C., which now uses less than 80 tons without lessening the work done, the waste gases escaping at 270° C.

Mr. E. M. Myers said that gaseous firing can supplant any coal-firing process, with economy in fuel sometimes as high as 50 per cent., and it is quite as easy to get oxidising or reducing atmosphere as with coal. It is much easier to control the temperature in gas-firing than in coal firing, and it is just as possible to obtain high temperatures with gas, and the furnaces have also a longer life. Blast-furnace gas (which contains 25 per cent. CO, 3·5 per cent. H, 12·5 per cent. CO_2 and 58 per cent. N) has not been mentioned, but is available. Coke-oven gas has a calorific value equal to that of town's gas. One pound of coal furnished about 3,300 British thermal units in the total volume of producer gas. About 1,200 British thermal units are necessary to coke 1 lb. of coal, while 200 British thermal units go to benzol. This leaves roughly 1,900 British thermal units in the surplus gas of specific gravity (air = 1). The chief difficulty is its lightness and tendency to rise through air; this may be remedied by putting the air port slightly in advance of the gas port, or by introducing hotter (and lighter air). There must be accurate control of pressure and quantity of gas and air at inlets, and also the pressure of the products of combustion at the outlet. Coke-oven gas will be the town's gas of the future. It is largely used in the United States, in one case as much as 150 miles from the generating station. The furnace efficiency is the ratio between the British thermal units used in practice and the calorific value of the fuel.

Mr. Wm. Bayliss stated that gas-firing is not the cheapest method in the production of steel. The report of a commission on nitrogen products proves conclusively that direct firing is cheapest for the production of electrical energy.

Colonel C. W. Thomas said a direct coal-fired continuous kiln compares favourably with a gas-fired kiln; the economy really arises in recuperation or regeneration. A continuous kiln of 28 chambers, coal-fired up to cone 9 down, was fed with ordinary South Staffordshire fuel (small nuts), the waste gases escaping at 150° C. to 200° C. The consumption was 2·2 cwt. to 1·8 cwt. to the ton of fire-bricks. More labour can possibly be saved with gas-firing, but there is no hope of any considerable economy of fuel.

Mr. Richmond briefly outlined his firm's experience of burning fireclay material in a gas-fired continuous kiln, which was erected in 1914, and has been in regular use since. The kiln is nominally divided into 22 chambers, the average chamber-capacity being 7,000 3-in. standard fire-bricks. The width of tunnel is 9 ft., and height to crown of arch 7 ft. 6 in. The gas producer (9 ft. by 6 ft.) is of ordinary fixed grate type. The main gas flue (3 ft.) runs round the whole length of the kiln, the service flues being 18 in. by 9 in., and the candle ports are four per flue; perforated candles 5 in. square and about 16 in. high are used. The fuel is washed treble nuts giving 11,750 cub. ft. of 21 c.p. gas per ton. This somewhat high-grade fuel gives a better length of flame and cleaner gas, and therefore less trouble in the flues. The finishing temperature of the clay (with a somewhat high percentage of alumina) lies between cones 12 and 13. The advantages of firing by gas fall under four heads; (1) Labour-saving. The kiln requires only three men on eight-hour shifts, whereas for similar output with Newcastle kilns, at least another man would be required for one shift to wheel coal and ashes. The kiln is so placed with respect to stoves and loading banks that further saving is effected. (2) Control of temperature. In the burning and pre-heating zones, uniformity of burning is made easily possible by perfect and simple control. (3) Waste is very low, and under-burned or over-burned material scarcely occurs. (4) Fuel costs amount to less than half of the cost in Newcastle kilns. The products drawn from the kiln have uniform appearance.

Dr. A. Granger's paper on "The Development of Continuous Kilns" was taken as read, and further discussion of the subject was postponed. Mr. W. Emery's paper on "The Casting of Gas Retorts" is withheld from publication for the present.

BRITISH BLAST-FURNACE PRACTICE.*

By FRED. CLEMENTS, M.Inst.C.E., M.I.Mech.E., &c. (The Park Gate Iron and Steel Company, Limited, Rotherham).

THE national importance of the economical production of pig-iron in its bearing on the manufacture of steel at competitive prices, as well as in its effect on other industries, cannot be over-estimated. In this country the whole subject deserves the closest investigation, so that any new installations which may be projected should be based on the latest facts and existing plants examined in the light of the best scientific data available.

We have to realise that both in America and Germany the development of the basal theories of blast-furnace operation has received more attention than is the case in this country. Classic work was done by Sir Lowthian Bell on the subject, and papers have been read from time to time before this Institution on various aspects of furnace work, but it is scarcely within the scope of any one man, or indeed of any one firm, under to-day's conditions to carry out, on a practical scale, the complete scientific research work which the importance of the subject justifies. This should be rather a matter for co-operation between ironmasters, and would undoubtedly produce results which would have very far-reaching effects on the industry. We have reached the present position almost entirely by the slow process of trial and error, modification and elimination. An expression of admiration of the several generations of men who, with unending patience and continual hard work, have raised blast-furnace practice to its present level should be made in passing. On the other hand, one cannot help commenting, with regret, upon the immense amount of valuable data, arising out of that long practical experience, which has been lost because it was not recorded and interpreted. This fact is most marked when it is necessary to face the design of a new plant. The search for helpful data is unproductive of anything satisfactory and definite, and the conclusion is forced upon the searcher that the only safe path is to do what some one else has done before; and so another opportunity for progress is lost. Circumstances such as these have led the author to record some of the information which he has collected and, after an effort to correlate this as far as possible, to arrive at some logical conclusions thus suggested. In carrying out this programme he has drawn freely on the records of the blast-furnace plant of the Park Gate Iron and Steel Company, Limited, which consists of three furnaces, all on modern lines, equipped with mechanical distribution, Cowper stoves and gas-driven blowing engines. Nos. 1 and 2 furnaces were built fourteen years ago and have been in service continuously since with one re-lining, whilst No. 3 furnace has been added during the war and was blown in in July, 1918. Other information has been freely supplied by several modern and progressive firms in the country, which has very materially helped.

Blast-furnace reactions are admittedly complicated, but unless satisfied with chemical accuracy regular working of the furnace cannot be expected. Yet of all exact metallurgical processes the reduction of iron in the blast furnace is probably the one which, at times, is controlled in the crudest fashion. This is no reflection on the blast-furnace manager, but rather redounds to his credit in so far that, with the meagre equipment and insufficient quantitative data with which he is usually supplied, he obtains such good results. In these days, when the ore supply is obtained from six or seven different sources of origin and the coke from even more different sources, it is physically impossible for any man, however able, to burden his furnace with the necessary exactitude by visual inspection only, aided by occasional laboratory analyses. The author has no hesitation in saying that many of the hanging and scaffolding troubles are directly due to incorrect burdening, and the wise blast-furnace manager, feeling this possibility, instinctively carries a higher weight of fuel than what he knows his furnace should really require, the excess being a burnt offering to show his respect to the unknown. The natural sequel to this argument is that any progressive blast-furnace plant should be equipped with its own laboratory, and chemists on the site, under the immediate direction of the furnace manager, and the duty of this chemical staff should be to keep the manager immediately advised of any change in the analyses of any of the materials used in the furnace.

The author's investigations show that it will be difficult to improve the heat absorbed side of the thermal balance of steel. Such reactions as the decomposition of the carbonate of lime might be performed outside the furnace, but it can be safely said that it would lead to no economy when the heat required for calcining exterior to the furnace is allowed for. It is doubtful whether drying off the moisture from the burden whilst outside the furnaces would lead to any real economy. There would be an equivalent increase in the sensible heat of the exit gases and consequently of their temperature. These would, however, be in a dryer and better state for combustion, but this fact is no help to the furnace itself, which after all is the limit of our consideration at the moment. The observed loss of 9 per cent. of the heat to the cooling water is not excessive, and could not be safely reduced with a thin-lined bosh. Only approximately 9 per cent. is lost by radiation and

* Abstract of paper read at the annual meeting of the Iron and Steel Institute, May 6 and 7, 1920. The paper was accompanied by elaborate tables giving detailed particulars as to the construction and working of blast furnaces in the different iron-making areas of the country. Owing to lack of space we are unable to produce these.—ED. E.

BRITISH BLAST-FURNACE PRACTICE.

ARRANGEMENT OF REVOLVING STOCK DISTRIBUTOR. PROTECTED DESIGN

Fig. 1. ELEVATION LOOKING IN DIRECTION OF ARROW AT "X"

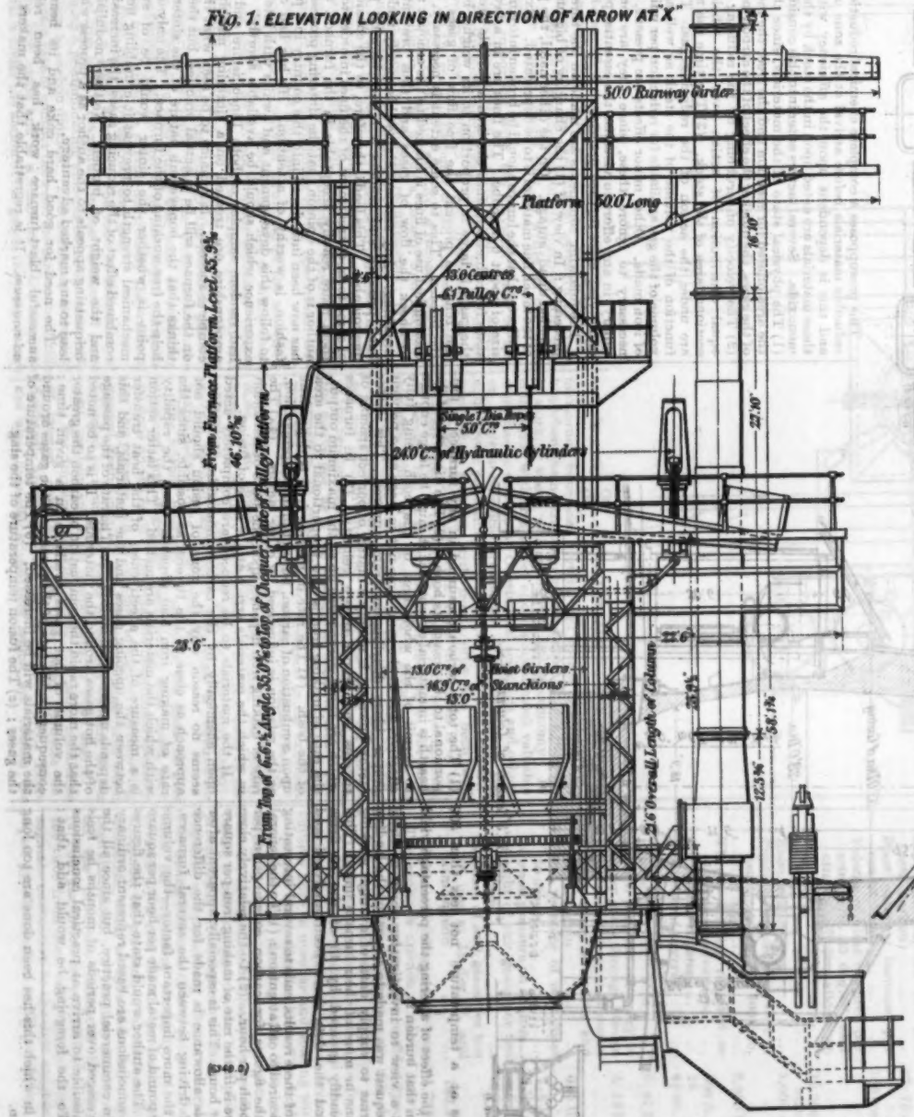
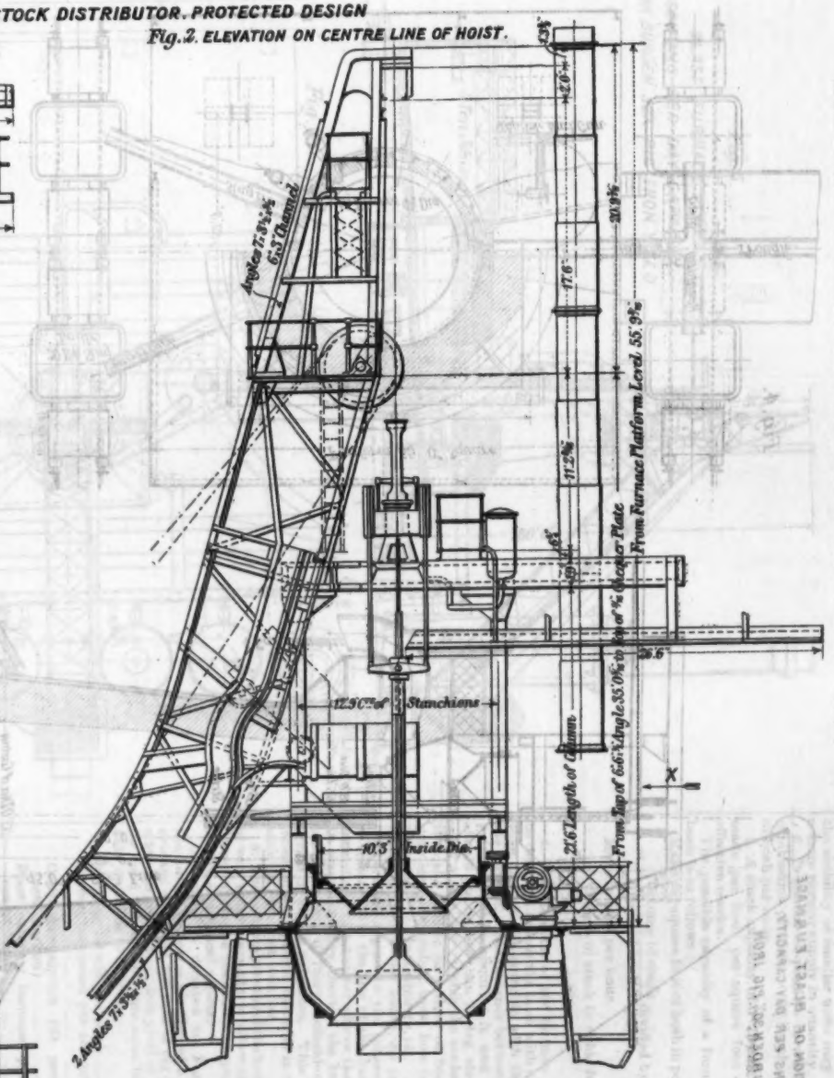


Fig. 2. ELEVATION ON CENTRE LINE OF HOIST.


Angles 5"x3½"x ⅝ Thwartd
From Furnace Platform Level 55'9"
From Top of 6 6"x Angle 35'0" to Top of ⅝ Gusset Plate
23'6"
12'3 C^rs of Stanchions
21'6 Length of Column
10'3 Inside Dia.
X
2 Angles 7"x3½"x ⅞

conduction through the foundations. On the heat generated side similar observations apply except that an increased amount of heat would be available from the carbon if more were burnt to carbon dioxide.

Arising out of the foregoing there appear to be two conclusions :—

1. That for a furnace built on good lines there is little hope of substantial economies being effected on the "Heat Absorbed" side of the balance-sheet.

2. That given a certain set of conditions as far as blast temperature is concerned the economy in carbon consumption depends entirely upon the proportion burnt to carbon dioxide, and therefore, under working conditions, the analysis of the exit gases is a direct reflex of the fuel economy condition of the furnace. It is admitted that the only carbon dioxide of value is that obtained from the reduction of the burden in the stack by the carbon monoxide. That derived from the dissociation of the limestone has no bearing on this point. Several questions naturally arise from the above deductions :—

(*a*) What is the physical condition of the burden most conducive to quick reaction ?

(*b*) What is the velocity of the gases through the burden which ensures the most effective reduction of iron oxide ?

(*c*) What is the effect of difference in the time the reducible materials are in contact with the active

BRITISH BLAST-FURNACE PRACTICE.

Fig. 3. ELEVATION OF BLAST FURNACE. 250 TONS PER DAY CAPACITY. ON BURDEN 30% PIG IRON YIELD.

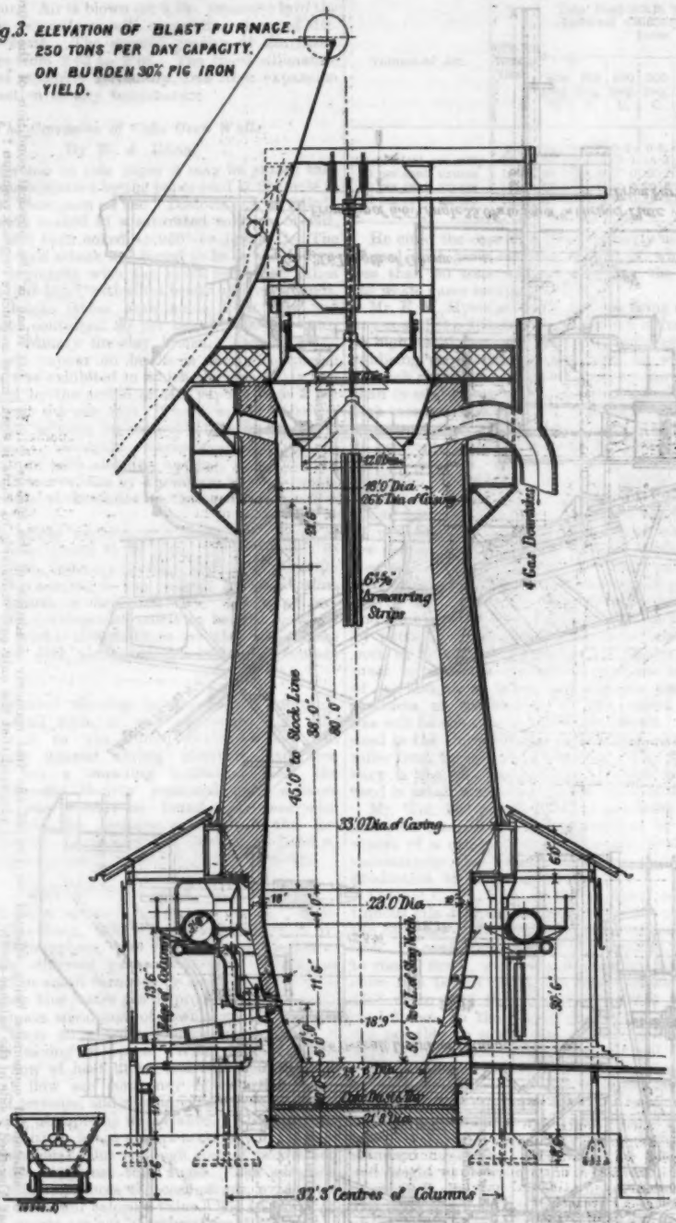
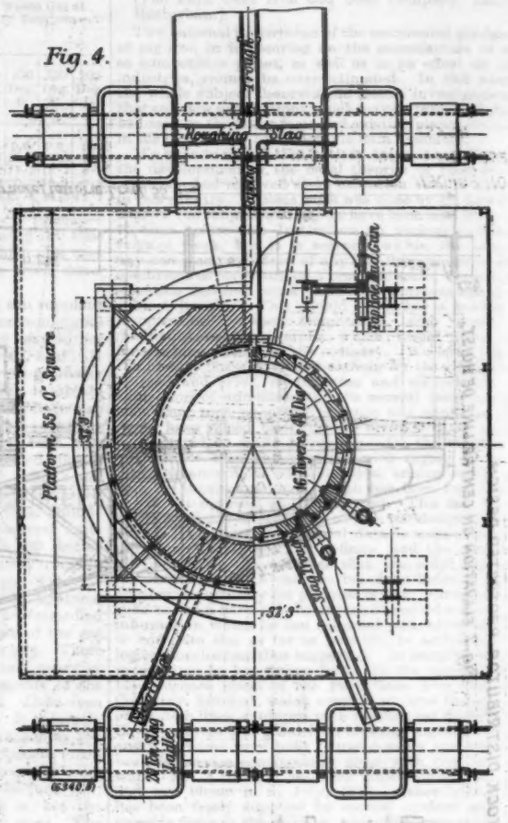


Fig. 4.



reducing gases at a temperature not less than 500 deg. F.?

(*d*) What is the effect of altering the percentage yield of pig-iron from that burden?

It was with a view to investigating some of these points that a request was made to several of the leading iron-making firms to supply data of average working conditions of one or more of their furnace units. This request was readily granted by 10 of the 12 firms approached, and the data have been analysed and scheduled.*

The analysis of these results leads to several interesting facts, and it is desired to call attention: (1) To the general constancy of the figures for carbon consumption per square foot of bosh per hour. (2) To the relatively close agreement there is in the rate of making iron per square foot of bosh per hour. This is especially apparent after some reasonable allowance is made for the difference in the rate of driving between the several furnaces, as well as for the more important factor—the volume of the stock per pound of metal made per hour per square foot of bosh. The author would state that the figures on which these conclusions are based represent ordinary returns made in commercial practice, but since all the figures were averaged over periods of months he feels that it is permissible to arrive at practical conclusions from them. To the foregoing he would add that:

(1) The total carbon consumed in any furnace is proportional to the area of its bosh. (2) The diameter of the hearth is immaterial except that it must be large enough to permit of the whole area of the bosh being fully effective, and at the same time not so large as to prevent proper blast distribution from tuyeres. This latter factor, however, is mainly a matter of correct spacing of tuyeres and proper tuyere velocity. (3) In furnaces which are being worked well up to the maximum output, the rate of making iron is also proportional to the area of the bosh. (4) The rate of making iron is dependent upon combustion of carbon, but not in direct proportion, as the relation is influenced by other factors. (4A) The rate of making iron depends upon the state of reduction in which the materials arrive at the zone of fusion.

If the materials to be reduced are completely acted upon chemically by the carbon monoxide, then there seems no reason why the zone of fusion should not approach as close to the tuyeres as possible, since the rate of making iron also depends upon the rapidity with which the materials are melted. This latter action is a measure of the effectiveness of the heat transfer between the upgoing gases and the materials, and this depends upon several factors: (*a*) The rate of the passage of the hot gases around the materials. It is to be noted that the more rapid the combustion of carbon the greater the volume of hot gases available in a given time; consequently, the rate of the passage of the gases around the materials will be increased. (*b*) The temperature of the gases; (*c*) The fusion temperature of the slag.

This presupposes a complete chemical reduction of the reducible materials before arrival at the zone of fusion, and this is dependent upon the efficiency with which these materials are acted upon in the stack by the carbon monoxide. Several factors enter into this consideration: (1) The physical state of the materials, since the larger the area offered for reaction and the freer the movement of the gases, the quicker the effect of the carbon monoxide. (2) The velocity of scrubbing by the reducing gas and equal distribution of action over the whole cross-sectional area of the stack. (3) The time the materials are under the action of the reducing gas. This is a function of the volume of the stack as well as of the volume of the gas available for reduction per unit weight of iron made. Other minor effects are present, but it is necessary to ignore these, since they are only subsidiary, in any effort to visualise the essential principles underlying blast-furnace practice.

The following comments are made on the three points preceding: In view of (1) the charging of big lumps is a decided disadvantage. On the other hand, the presence of too much fine material is to be deprecated. Experience indicates that the lumps should be broken into a moderate size of about 6-in. cube. The fines are in a favourable state for reduction, since the area a particle presents to the gases is large in proportion to its weight, but their use tends to prevent the free flow of gases through the burden. This to some extent is necessary, but the economical use of fines is limited to the amount required to check the flow of gases and thus prevent short-circuiting. Any amount above this merely adds to the back pressure and renders a higher blowing pressure unavoidable. This leads, therefore, to the consideration of some form of treatment of the fines in order to render them more readily acceptable in the furnace, and the author is of the opinion that the sintering process, which has now been introduced into this country in a practical fashion, is worthy of attention. He has had occasion to follow this development and awaits with interest the experience which should be available shortly. He has had random samples of both Lincolnshire and Northamptonshire ore treated on a sintering machine with complete success. It remains to be seen what the effect on the furnace will be in actual practice, but the author thinks that the honeycomb nature of the sinter should help the free working of the furnace. The only doubtful point is whether the sinter would be of sufficient mechanical strength to prevent it crumbling under the combined effect of the reducing gases, the increasing heat and the weight of burden. Neither nodulising nor briquetting appeals to the author as a process which can lead to any marked advantage.

The need for good hard coke and its bearing on successful blast-furnace work has been reiterated *ad nauseam*. It is regrettable that the makers of coke

* The tables in which this has been done are too long for reproduction.

BRITISH BLAST-FURNACE PRACTICE.

Fig. 5.

BLAST FURNACE PLANT
250 TONS PER DAY CAPACITY
ON BURDEN 30% PIG IRON YIELD

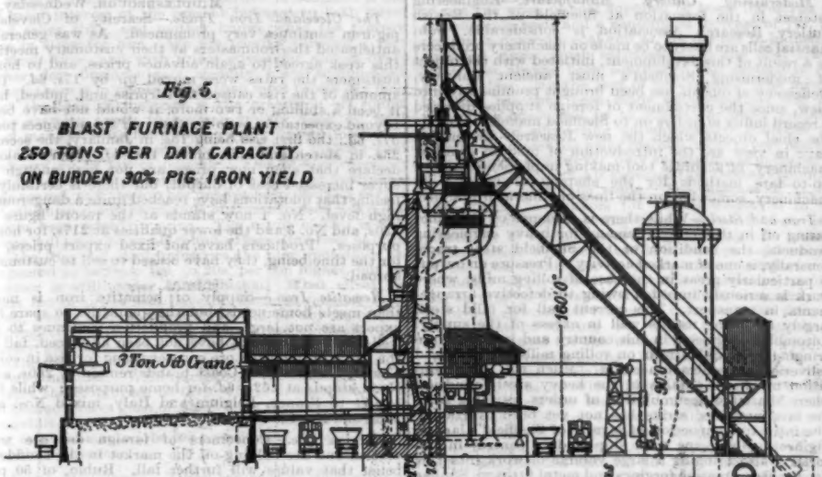
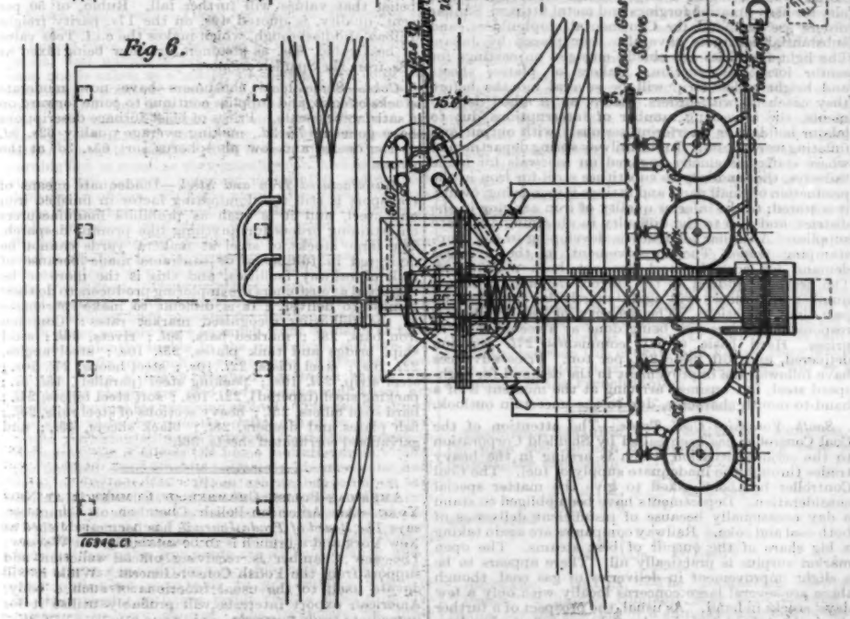


Fig. 6.



should be satisfied with the present condition of things. A determined effort ought to be made to see what can be done to improve the mechanical strength of their product without deterioration of its quality. On this subject the author admits that he writes as one with little hope.

Equally important with the physical state of the materials is the question of distribution. This admits of a perfectly good mechanical solution, and the author ventures to draw attention to the illustrations (Figs. 1 and 2) of the stock distributor which is at work on the No. 3 furnace, Park Gate, and No. 4 furnace, Staveley. This distributor is the author's patent, and has been designed to meet the following requirements: (1) Even distribution around the large bell; (2) equal distribution of large and fine material; (3) means to load the furnace in emergency at any one point; (4) top to be gastight; (5) means for changing bell, rods or other gear with minimum loss of time; (6) complete control by the attendant in the control-house of all operations, and effective indication of the same.

Regarding the velocity of scrubbing of the materials by the reducing gas, it is obviously not of much value to expose area if we do not provide sufficient volume of carbon monoxide to attack the surface of the material for reduction vigorously. It is quite easy to see that in a furnace not working fast enough the reducing gas will not necessarily distribute over the whole area of the furnace. Therefore throughout the zone of reduction sufficient rapidity of movement of the carbon monoxide must be maintained to expose continually the oxide of iron to fresh attacks by the reducing gas.

There is a point at which the rate of reduction of oxide of iron is at a maximum in the presence of gases containing a predominating amount of carbon monoxide in relation to carbon dioxide. This maximum is reached at a certain rate of contact between the carbon monoxide and the iron oxide and is a function of the time the material is under the action of the gases, the temperature and the ratio $\frac{CO}{CO_2}$. If a furnace is working below this maximum beneficial results will follow speeding up, but when the maximum is reached then further increase in working speed will result in a fall of economy. In connection with this aspect of the subject much valuable work has been done by Continental scientists and others on physico-chemical reactions. The data for the equilibrium conditions of CO to CO_2 ratio and temperature when reacting with iron oxides has been well developed, but, whilst work along these lines is of the greatest value, in the author's opinion the investigations at present fail in so far as the limitation of the time element, which is so pronounced in actual practice, is ignored. Again, the effect of the presence of slag-forming materials intimately mixed with the iron oxides has not been investigated, nor is the result yet known of the predominating proportion of nitrogen present with the active gas, as is the case in the blast furnace. The information in relation to blast-furnace reactions is reviewed by Professor Dr. R. Kremann in his excellent book on "The Application of Physico-chemical Theory," which has been translated into English by H. E. Potts, M.Sc. The objection which the author has raised, however, is entirely overlooked by Dr. Kremann in his exposition. It is on points such as these that experimental research work on a large scale is required to enable definite data to be arrived at.

The author hesitates to construe the data he has obtained into dogmatic conclusions; this could only be done on the basis of information determined specially for this purpose, but he ventures to suggest the following general deductions for furnaces using home ores when adjusted to a uniform basis of burden yielding 30 per cent. pig-iron and blast temperature of 1,000 deg. F.

1. For furnaces working under the same conditions of burden, coke and blast, the larger furnaces undoubtedly show an advantage in fuel economy. There are also financial advantages which are outside the scope of this paper, such as reduced standing charges, &c. The big furnace, however, has disadvantages since, in a plant supplying a steel works with molten metal, the mobility of smaller units may be an asset in giving a more regular supply in quantity.

2. It should be possible to work at a rate of carbon combustion of 55 lb. to 60 lb. of carbon per square foot of bosh per hour.

3. A stack capacity of 0·75 cub. ft. per pound of iron made per hour per square foot of bosh should give effective results.

The possible capacity of a furnace therefore on this basis is as follows:

Make per square foot of bosh in pounds per hour.

$$= \left[\frac{\text{Volume of stack}}{\text{Area of bosh}} \text{ divided by } 0{\cdot}75\right] \text{ lb. per hr.}$$

Make in tons per hour.

$$= \left[\frac{\text{Volume of stack in cubic feet}}{1{,}680}\right] \text{ tons per hour.}$$

4. The diameter of the furnace at the tuyeres should be designed to suit the bosh with a view to arranging the zone of fusion to coincide with the biggest diameter of the furnace. The distance between the tuyeres and this point should be about 10 ft. and the walls of the bosh should not be less than 75 deg. slope.

As a corollary on this the author ventures to suggest that the success or failure of bosh tuyeres in present practice is dependent upon how far they help to create the conditions indicated in (4). If they happen to be placed correctly they assist, by producing an increased temperature higher in the furnace, in lifting the zone of fusion up to the top of the bosh, which, in ordinary construction, is too far above the level of the tuyeres. In essentials they shorten the height of the bosh and bring the zone of fusion coincident with the end of the period of active reduction. This prevents the accumulation of semi-plastic material in the region of the bosh with its resultant troubles.

5. The blowing plant and the hot-blast stoves should be of very ample capacity to allow the furnace to be easily driven up to the maximum output conditions necessary to give economical results.

Attention is directed to Figs. 3 to 6, in which the author indicates his idea of a furnace capable of an average output of 250 tons of pig-iron per 24 hours from a burden giving a pig-iron yield of 30 per cent. Allowing for good South Yorkshire coke being used, some of the data would be as follows:—

Average output per week ...	1,750 tons.
Carbon consumed per ton of iron	19·24 cwt.
Coke consumption (81 per cent. carbon)	23·75 cwt.
Blast entering furnaces per ton of iron	100 cwt.
Volume of blast required per minute at 80 deg. F. and atmosphere (no allowance for losses)	29,000 cub. ft. per minute.
Blast temperature	1,000 deg. F.
Penetrative force per foot of hearth radius, per 100 cub. ft. of blast	2,000 lb.
Tuyere velocity required to give penetrative force ...	590 ft. per second.
Number of tuyeres	16.
Diameter of tuyeres ...	4¼-in.
Pressure drop through tuyeres	0·81 lb. per sq. in.
Hearth pressure necessary to carry gases through burden	6·19 lb. per sq. in.
Allowance of drop in pressure from entry to stoves and tuyere main	0·5 lb. per sq. in.
Total pressure of cold blast to stoves	7·5 lb per sq. in.
Normal pressure on engines...	8 lb. per sq. in.
Weight of exit gases per ton of iron	126 cwt.
Volume of exit gases per ton of iron at 32 deg. F. and atmosphere	169,340 cub. ft.
Volume of exit gases per hour	1,795,000 cub. ft.

The author's opinion is that a greater output than the average stated could be confidently anticipated from the furnace. With reference to this design there are several points to which attention may be directed: (1) The furnace stack is carried on four columns only, thus leaving the platform around the furnace clear of obstructions and permitting an arrangement of the tuyeres both in number and spacing with a view solely to proper blast distribution. The bosh is also easily accessible for cleaning. (2) Two connections are arranged to the tuyere main, one on each side of the furnace, to equalise the blast pressure all round. (3) The casing is continuous from the lintel plate to the hearth, presenting a clear, smooth surface, no brickwork being exposed, and permitting efficient external water cooling. The casing makes a sliding joint at the lintel plate to allow for expansion vertically. (4) The platform is covered by a roof for the protection of the workmen, and under the platform level the furnace hearth is easily accessible, water troughs and other obstructions having been eliminated. (5) The lines of the furnace are designed on the principles indicated by the investigations. (6) Four gas outlets are provided at the top of the furnace, the tube from each being carried down and making a separate connection to the dust catcher to ensure more equal gas distribution at the stock line. (7) The stock

distributing gear is similar to that now in use on Park Gate No. 3 and Staveley No. 4 furnaces, as represented in Figs. 1 and 2, page 647. (8) All parts of the furnace are designed with a view to simplicity, accessibility, safety and first-class mechanical construction. (9) All main gas tubes and distributing tubes are carried overhead.

The general lay-out shown in Figs. 5 and 6 is only intended to be indicative of the arrangement proposed of the furnace, stoves, dust catcher and immediate accessories. Schemes for dealing with the important

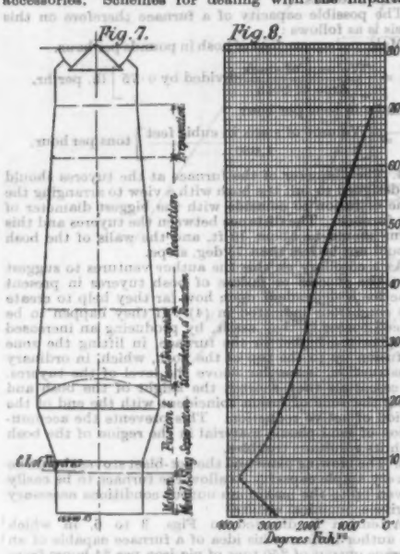


Diagram of blast-furnace showing approximate zones of reaction and temperature curve,

NOTE.—The temperature curve is based on published information extended by further data of the temperature in the furnace hearth.

question of handling the ore, cleaning of the gas and provision of the blowing plant have been considered, but are not shown in order that the main issue should not be obscured.

The approximate zones of reaction and temperature gradients are as represented in Figs. 7 and 8.

It is not possible in the limits of one paper even to indicate all the necessary points which arise in an investigation such as this. Many papers, indeed books, would have to be written to set forth adequately the arguments leading to the conclusions arrived at, but the author trusts sufficient has been said to make clear to those familiar with blast-furnace practice the path along which his own thoughts have led him. If this has been achieved and interest stimulated the author is satisfied with his effort.

UNIVERSITY OF BRISTOL—FACULTY OF ENGINEERING.—When the university was established in 1909, Bristol possessed one of the best-equipped engineering faculties in the United Kingdom; but since then great improvements have taken place in many other universities, and the time has come when the Bristol Engineering Faculty needs further equipment. The Merchant Venturers, in whose college the Faculty is provided and maintained, have decided, therefore, to undertake considerable extensions; they are roofing in a large space at the back of the college which will provide a new laboratory, 68 ft. by 50 ft. At present the testing laboratory in the Department of Civil Engineering, and the heat engines laboratory in the Department of Mechanical Engineering, share a large room; this room will in future be devoted to the work of the Department of Civil Engineering only, which will enable much additional apparatus to be installed. The new laboratory will be allotted to the Department of Mechanical Engineering and will contain the additional plant and instruments. An additional workshop for the use of the mechanics who are engaged in producing apparatus for research work and for the use of students will be equipped as well as a new metallographic laboratory. The civil engineering laboratory will be equipped with additional testing machines. The laboratory accommodation at the disposal of the Department of Electrical Engineering will be doubled; three of the present class-rooms being used for this purpose. The equipment of the department will be enlarged and improved. For the Department of Automobile Engineering a new experimental motor car is on order, and other additions will include a Froude dynamometer, additional experimental engines, a flowmeter and specimens of different automobile engineering components. The equipment of the boiler-house will also be improved. The main engineering workshop will be re-equipped with new machine tools and plant. The total cost of these alterations and additions will amount to about 11,000*l.* It is hoped that a considerable part of them will be available for use during next session, when the number of advanced students in the Faculty will be greatly increased. Last term there were 1,340 students in the Faculty, 271 in the day time and 1,069 in the evening.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Modernising Cutlery Manufacture.—Engineering interest in the formation at Sheffield of the British Cutlery Research Association is considerable. Substantial calls are likely to be made on machinery producers as a result of this development, initiated with the object of modernising Sheffield's most ancient industry. Deficiency of output has been brought prominently into view, since the curtailment of foreign supplies diverted a record influx of orders on to Sheffield makers. Among the chief objects which the new Research Association have in view are the introduction of modern grinding machinery, of accurate tool-making implements, and of up-to-date methods for the shaping of handles by machinery, somewhat on the lines of American practice.

Iron and Steel.—While there is evidence of a distinct easing off in the foreign demand for heavy engineering products, the condition of the Sheffield steel trade generally, is one of marked activity. Pressure on output is particularly great in the case of rolling mills, where work is seriously impeded owing to defective arrangements in transport. The current call for mild steel, largely for home use, is well in excess of the supply. Automobile engineers in this country and in France are bringing pressure to bear on rolling mills for increased deliveries on contract account. Much the same condition of affairs obtains in the heavy steel foundries, where the large accumulation of orders resulting from the last moulders' strike has not yet been overtaken. The intimate connection of several of Sheffield's largest engineering concerns with shipbuilding centres in the north is also bringing a large volume of work into this city for heavy marine forgings and metal fittings. Similar orders are on hand for Continental shipbuilders, and substantial contracts have also been placed by Japan. The light foundries are chiefly engaged on castings for motor lorry construction. Makers of plates, sheets and bright rolled strip will be several months before they catch up with orders. Here, as in allied departments, the increasing number of interruptions due to labour holidays is interfering seriously with output and inflating works costs. In the railway spring departments, where staffs are chiefly engaged on renewals for home railways, the tendency to substitute steel for iron in the production of small parts and fittings is increasing, owing, it is stated, to the inferior quality of iron arriving in the district, and also to the difficulty in obtaining adequate supplies. A similar tendency is developing in the drop-stamping trade. The improvement in the overseas demand for crucible steel has not been maintained. The prospect, judged on the current demand, is that a number of furnaces will again shortly be employed on part-time operations. The scarcity of basic billets is responsible for business being done at a record level of prices. Hard basic to-day commands 27*l.* per ton delivered, and soft basic 26*l.* per ton. Price advances have followed the improvement in the demand for high-speed steel, but business arriving at the moment is of a hand-to-mouth character, due to the uncertain outlook.

South Yorkshire Coal Trade.—The attention of the Coal Controller has been called by Sheffield Corporation to the serious situation which is arising in the heavy trades through the inadequate supply of fuel. The Coal Controller has been asked to give the matter special consideration. Departments have been obliged to stand a day occasionally because of insufficient deliveries of both coal and coke. Railway companies are again taking a big share of the output of best steams. The open market surplus is practically nil. There appears to be a slight improvement in deliveries of gas coal, though there are several large concerns locally with only a few days' stocks in hand. As usual, the prospect of a further rise in household fuel, has brought an influx of orders, but as merchants are already labouring under a great weight of arrears, they are not seriously affected. Quotations:—Best branch hand-picked, 37*s.* 2*d.* to 38*s.* 2*d.*; Barnsley best silkstone, 37*s.* 2*d.* to 37*s.* 8*d.*; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.*; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.*; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.*; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.*; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.*; nutty, 27*s.* 2*d.* to 28*s.* 2*d.*; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

MIDDLESBROUGH PIG-IRON SHIPMENTS.—From the statement published by Messrs. William Jacks and Co., 5, East India-avenue, E.C., we find that the shipments of pig-iron from Middlesbrough, including Skinningrove, in April last, were 18,090 tons coastwise and 33,750 tons foreign, a total of 51,840 tons, as compared with 22,773 tons in April, 1919, and 35,851 tons in April, 1918. The total for April last was the largest for many months past; it included large increases to Wales, Newcastle, other English ports and Italy.

EMPIRE MOTOR FUELS COMMITTEE.—The terms of reference of this committee, as stated by the Imperial Motor Transport Council, are: (1) To take immediate steps to encourage and develop the production and utilisation of additional motor fuel supplies or raw materials therefor in all parts of the Empire, and more particularly to ensure increasing shipments of motor fuels to Great Britain, and, so far as may be necessary, to the Empire overseas. (2) To co-operate with any Government or incorporated or unincorporated body of persons in order to further that object. (3) To offer for the purposes in view bonuses or other rewards, and to incur such expenditure as may be desirable, all such expenditure being subject to the approval of the council.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Scarcity of Cleveland pig-iron continues very pronounced. As was generally anticipated the ironmasters at their customary meeting this week agreed to again advance prices, and to home customers the rates were moved up by 17*s.* 6*d.* The amount of the rise caused no surprise and, indeed, had it been a shilling or two more, it would not have been beyond expectation. So far this year the advances total 57*s.* 6*d.*, the first rise being 15*s.* in January, the second 25*s.* in March and this month 17*s.* 6*d.* Many makers declare that even now prices are not high enough to cover increased cost of output, but there is certainly a feeling that quotations have reached quite a dangerously high level. No. 1 now stands at the record figure of 230*s.* and No. 3 and the lower qualities at 217*s.* for home purposes. Producers have not fixed export prices, as for the time being, they have ceased to sell to customers abroad.

Hematite Iron.—Supply of hematite iron is more than meets home needs, but the quantities to spare for export are not large, and production continues to be well taken up. Prices have not been advanced, fall in the value of imported ore compensating for rise in coke. Nos. 1, 2 and 3 East Coast brands remain at 260*s.* and No. 1 stands at 262*s.* 6*d.* for home purposes; while for export to France, Belgium and Italy, mixed Nos. are 265*s.* and No. 1 is 267*s.* 6*d.*

Foreign Ore.—Consumers of foreign ore are well placed, and are holding off the market in the confident belief that values will further fall. Rubio, of 50 per cent. quality, is quoted 49*s.* on the 17*s.* parity freight Bilbao-Middlesbrough, which makes the c.i.f. Tees value of best rubio, 60*s.* as steamers are now being fixed at 28*s.* from the Spanish ore port.

Coke.—Some local consumers have now moderate stocks of coke, and supplies continue to come forward on a satisfactory scale. Prices of blast-furnace descriptions have gone up 7*s.* 3*d.*, making average quality 62*s.* 9*d.* at the ovens, and low phosphorus sort 65*s.* 3*d.* at the ovens.

Manufactured Iron and Steel.—Inadequate means of transport is still the dominating factor in finished iron and steel, and it is such as prohibits manufacturers entertaining orders for anything like prompt despatch. The large stocks of steel at makers' yards cannot be delivered in fulfilment of contracts made because of lack of railway facilities, and this is the more to be regretted as customers are imploring producers to do their utmost to deliver. It is difficult to make purchases at the following recognised market rates: Common iron bars, 28*l.*; marked bars, 30*l.*; rivets, 36*l.*; steel ship, bridge and tank plates, 23*l.* 10*s.*; steel angles, 22*l.* 10*s.*; steel joists, 22*l.* 10*s.*; steel hoops, 27*l.* 10*s.*; steel strip, 27*l.* 10*s.*; packing steel (parallel), 18*l.* 5*s.*; packing steel (tapered), 22*l.* 10*s.*; soft steel billets, 24*l.*; hard steel billets, 25*l.*; heavy sections of steel rails, 23*l.*; fish plates and sleepers, 28*l.*; black sheets, 45*l.*; and galvanised corrugated sheets, 56*l.*

AMERICAN-POLISH CHAMBER OF COMMERCE AT NEW YORK.—An American-Polish Chamber of Commerce, says *The Board of Trade Journal*, has been established at New York and a branch is to be established at Warsaw. The new Chamber is receiving official sanction and support from the Polish Consul-General. While it will devote itself to the usual functions of such a body, American export interests will probably utilise it for immediate trade purposes.

THE ASSOCIATION OF ENGINEERS-IN-CHARGE.—The annual dinners of this association, which have been suspended since 1914, were resumed on Saturday last, when about 150 members and guests assembled at the Holborn Restaurant, London, Mr. Frank Bailey, President of the Association, taking the chair. Speaking to the toast of "Industry and Education," Dr. H. S. Hele-Shaw referred to the new Education Bill, the wide-reaching effects of which, he said, were not yet fully realised. Better education was essential if the people were to use their power aright. In the meantime it was necessary for engineers and others to assist the Minister of Labour in his task of tiding over the difficult period which must exist before the benefits of the new act could be felt. In responding to the toast the Right Hon. T. J. Macnamara, the Minister of Labour, referred to the objects and work of the association, and to the development of engineering science in recent years. He fully appreciated, he said, the responsibilities of his office, but his task was lightened by his belief in the good sense of the great majority of the people and by the loyal assistance of his colleagues at the Ministry. Mr. H. P. Boulnois, in proposing the toast of "The Association," referred to the inadequate remuneration of brain workers, and, in replying, the chairman said the association existed for the mutual help of its members, but it was not a trade union and could take no part in any form of coercive tyranny. He also referred to the circumstances which led to the formation of the Metropolitan Munitions Committee and to some of the work of that body, of which, we may mention, Mr. Bailey was himself a leading spirit. Tributes to Mr. Bailey's work were paid by Mr. J. E. Watkins and by Mr. A. E. Penn, the honorary secretary of the association. Captain Sankey and Sir J. E. Petavel also spoke. An extensive musical programme was provided for the entertainment of the members and guests, and the whole evening was highly successful from every point of view.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

State of Trade.—The trade position in Scotland is one of great interest at the present moment to both buyer and seller alike, and neither knows what the morrow has in store for him. We are passing through a very difficult time, and with prices advancing almost every other day business gets steadily more complicated. Work there is in plenty, more than most trades can face, but the lack of material is the drawback all round. The scarcity seems to become greater week by week and managements have to use every known method of avoiding any waste whatsoever and of making each delivery go as far as possible. This is also necessary owing to the enormously high price to which everything has soared, and the top has not yet been reached, as fuel, of which so many thousands of tons are used daily, has again been raised in price. The result of this is that there will again be an all-round advance in prices at once. In the iron and steel industries the new quotations are expected to be from 10*s.* to 20*s.* per ton higher, but the matter is still under consideration. What effect the next list of prices will have on business remains to be seen, but it is doubtful if there will be any immediate falling-off in demand owing to the great world shortage. Every general advance is followed by another demand on the part of labour for more money, and so the vicious circle continues. With reference to the shortage of steel plates the employees in three of the locomotive works in Glasgow have gone on short time this week, working one shift less, and in some of the shipyards and engineering establishments jobs are occasionally getting held up for similar reasons.

Scotch Steel Trade.—There has been no slackening in the demand for steel of all kinds during the past week, as buyers have become resigned to their fate as regards prices, and advances are so frequent nowadays that each one is taken as a matter of course. But from the consumers' point of view it is delivery which really matters and that is getting no better. On all sides we learn of different industries being partially held up through shortage of plates, &c., and this of course is rather a serious matter. The Scotch steel makers are turning out as much as they possibly can, and as circumstances will permit, but raw material is scarce and difficult to obtain, with the result that operations are being somewhat hampered. The demand for plates is really enormous and many months must pass before the present orders are fulfilled, and inquiries now in the market amount to a large tonnage. If many of these are accepted the probable date of delivery must be a long way ahead. There is also a large outlet for structural sections, and makers' books are well filled up and consumers keep pressing for further supplies. The black sheet makers have as much work on hand as they can conveniently tackle in the meantime, and are not anxious to fix up much more business at present. Not only is there a heavy demand for black sheets but galvanised sheets are also very active and there are plenty of buyers for anything offered. The export side of the steel industry remains quiet owing to the home trades requiring so much material, and this is good in the sense that it allows the home manufacturers to ship the finished article, which certainly increases the final value of our exports. Prices are unchanged from last week, but now that fuel is officially raised and pig-iron is dearer the steel prices are bound to be advanced also.

Malleable Iron Trade.—The conditions in the West of Scotland malleable iron trade are without change, and a very strong demand prevails. All users of bar iron are busy and none seem able to get supplies adequate to their needs, with the result that a hand-to-mouth existence is very general. The producers are quite unable to obviate this state of matters as everybody seems to keep clamouring for stuff. Prices are firm, with an upward tendency.

Scotch Pig-Iron Trade.—The activity in the Scotch pig-iron trade continues, and consumers of foundry iron are still rapidly getting through as much as they can secure, but in some cases that does not amount to anything very great owing to the general scarcity. Buyers keep pressing for supplies of foundry iron, as also for hematite iron, which latter is in great demand by the local steel-makers. Prices are very high, and with fuel now up by 4*s.* 2*d.* per ton the quotations for pig-iron are being raised again.

SYSTEMATIC ERRORS IN LEVELLING.—The Egyptian Survey department have just published an interesting paper by Mr. J. H. Cole on the systematic errors which have been observed in precise levelling along the course of the Blue Nile. The practice of the Egyptian Survey department has been to run the lines of levels, both backwards and forwards between two permanent bench marks, but in spite of all precautions taken to balance the distances between instrument and staff, and other subsidiary precautions, a systematic error has always been found. In general the effect has been the same as if the back staff reading were systematically too small, and the fore staff reading too great. The amount is not large, the discrepancy ranging from 0·14 to 0·47 mm. per km. in the case of precision work and from 0·5 mm. to 8 mm. per km. in second order work. Mr. Cole has arrived at the conclusion that the effect is due to systematic variations in the atmospheric refraction near ground level, which differs in the morning and afternoon. Hence if the forward set of levels chances to be taken in one direction in the morning, and in the reverse direction in the afternoon, there will be a discrepancy due to the difference on the atmospheric refraction.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Markets.—The decision of the Government to put the price of coal supplied to home industries on an economic basis and a consequent increase of 14*s.* 2*d.* per ton in domestic coal and 4*s.* 2*d.* per ton in industrial coal has given much satisfaction to the coal trade, for it has always been considered bad finance to sell coals at less than the cost of production. The mining industry has thus been made self-supporting and the immediate effect will be to release for other purposes than that of supporting unremunerative collieries the high profits which are being realised in the export market. The new step is, however, only an instalment of decontrol of the coal trade, and it is expected that further announcements will shortly be made. The increase of 4*s.* 2*d.* also applies to bunkers for vessels employed in the United Kingdom coasting trade, so that there is a possibility of the maximum freights being also revised. In connection with decontrol it is the reported intention of the Coal Controller to make arrangements for an abundant supply of coal for home industries and to allow the surplus to be exported. This, it is estimated, will involve a substantial reduction in exports for the estimated output during the next twelve months is 240,000,000 tons for the whole of the United Kingdom, and home requirements 215,000,000 tons, leaving 25,000,000 tons available for export, as compared with 78,000,000 tons in 1913. Shipments from South Wales to foreign ports last week amounted to 264,831 tons, a decrease of 70,782 tons compared with the previous week. France received 135,634 tons, Italy 29,770 tons and British coaling stations 43,325 tons. The Coal Controller has decided that for the next couple of months South Wales collieries are to supply home railways with 60,000 tons of coal weekly, and the allocation for this quantity has been equally divided amongst all the collieries, and not mainly between Monmouthshire pits as has been the case in the past couple of months. These allocations and the requirements of home industries and bunkers for vessels in the foreign and coastwise trade absorb practically the whole of current outputs, and the result is that there is little free coal on the market. Again, release of large coals is practically suspended for places other than Italy and British coaling stations, and shippers to France, &c., have to take throughs and smalls, for which sellers demand 110*s.* and 97*s.* 6*d.* respectively. New business in the circumstances is quiet, and though there has been a considerable diminution in the number of boats waiting in the roads for cargoes there is still a congestion of tonnage at the South Wales ports.

The Iron and Steel Trades.—Though the inquiry for tin plates has eased off, prices show no material alteration as manufacturers in most cases are fully booked up and not in need of new business. Standard boxes of tin plates are quoted at 72*s.* to 74*s.*, and with the rate of exchange between this country and France more favourable to the latter it is expected that there will be an expansion in the French inquiry.

REDUCTION GEARING ON STEAMSHIPS: ERRATUM.—On page 600, column 3, one-third way up from the bottom, the expression

$$\frac{1}{2R} = \left(\frac{1}{D_0} + \frac{1}{D_1}\right) \sin\theta \cos\phi$$

should read

$$\frac{1}{2R} = \left(\frac{1}{D_0} + \frac{1}{D_1}\right) \frac{\cos\phi}{\sin\theta}.$$

SHIPYARD "BRAILA."—The Roumanian shipyard "Braila," a limited company, has been founded at Braila, for the starting of a ship-repairing and building plant as well as engineering works. A good site was obtained on the banks of the Danube, which is not too far from the town, and is adequate for the business in view. The statutory capital is of Lei 15,000,000 (600,000*l.* at normal exchange rate), of which Lei 3,000,000 have already been issued. Amongst the founders are the bank of Messrs. Marmorosch, Blank and Co.; "Dunarea" River Navigation Company; "Maritima" Steamship Company; "Cometa" Oil Refinery; Cantacuzino Portland Cement Works, &c., &c. General C. Cantacuzino is president and Consul Victor B. Mendl, vice-president.

THE RAILWAY YEAR BOOK.—Several new features are incorporated in the 1920 edition of "The Railway Year Book," a copy of which has just been received from the Railway Publishing Company, Limited, 30, Fetter-lane, Fleet-street, London, E.C. 4. The current issue gives complete details and historical statistics of 51 railway systems of the British Isles, accompanied, in most cases, by a map, as well as a mass of railway statistics and data of a more general nature. Particulars are given, for the first time, of the organisation and *personnel* of the Ministry of Transport, and another new feature is the inclusion of dimensioned diagrams of the loading gauges of the more important British lines for comparison with the Berne Conference gauge and the proposed standard gauge for Great Britain. The section giving biographical sketches of British railway officials has been considerably extended, and the information relating to the railways in the British Dominions, and in certain foreign countries in which British interests are considerable, has been rendered more complete. The additions, however, while enhancing the claim of the work to be regarded as the "Railway Whitaker," do not affect its general arrangement, with which railway officers, at home and abroad, have now been familiar for twenty-three years. The price is the same as that of the last edition, viz., 5*s.* net.

NOTICES OF MEETINGS.

THE PHYSICAL SOCIETY OF LONDON.—Friday, May 14, at 5 p.m., Meeting at the Imperial College of Science, Imperial Institute-road, South Kensington, London S.W. (1) Demonstration of Experiments on the Thermionic Properties of Hot Filaments, by Dr. F. Lloyd Hopwood; (2) "A Modified Theory of Crookes' Radiometer," by Mr. G. D. West; (3) "On the Magnetic Properties of Silicon-Iron (Stalloy) in Alternating Fields of Low Value," by Mr. A. Campbell; (4) "On Tracing Rays through an Optical System," by Mr. T. Smith.

THE ROYAL SOCIETY OF ARTS.—Monday, May 17, at 8 p.m.: Cantor Lecture, "The Decoration and Architecture of Robert Adam and Sir John Soane, 1758–1837," by Mr. Arthur Thomas Bolton, F.R.I.B.A., F.S.A., Curator, Soane Museum (Lecture III). Wednesday, May 19, at 4.30 p.m.: Ordinary Meeting, "The Commercial Applications of Electrical Osmosis," by Mr. John Somerville Highfield, M.Inst.C.E., M.I.E.E., Mr. W. R. Ormandy, D.Sc., F.C.S., and Mr. D. Northall-Laurie, F.I.C.; Mr. Alan A. Campbell Swinton, F.R.S., Vice-President of the society, will preside. Thursday, May 20, at 4.30 p.m.: Indian Section, "Roads and Transport in India," by Brigadier-General Lord Montagu of Beaulieu, K.C.I.E., C.S.I., Adviser on Mechanical Transport Services in India, 1915–19; Lieutenant-General Sir Herbert V. Cox, K.C.B., K.C.M.G., C.S.I., Military Secretary, India Office, will preside.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, May 18, at 5.30 p.m., Meeting of the Institution at the House of the Royal Society of Arts, John-street, Adelphi, W.C. 2. The following paper will be read: "Air Lift System of Pumping Oil Wells," by Mr. R. Stirling, M.Inst.C.E., M.I.Mech.E. The chair will be taken by the president, Sir Frederick W. Black, K.C.B.

THE ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May 19, at 5 p.m., at 70, Victoria-street, Westminster. Papers to be read: (1) "Agricultural Climatology of Australia," by Dr. Griffith Taylor (Commonwealth Bureau of Meteorology, Melbourne); (2) "Report on the Phenological Observations for 1919," by Mr. J. E. Clark, B.Sc., and H. B. Adames.

THE SOCIETY OF GLASS TECHNOLOGY.—Wednesday, May 19, at 2 p.m., meeting in the Rooms of the Institute of Chemistry, 30, Russell-square, London, W.C. 1. General discussion on "The Physical Properties of Glass." The discussion will be opened by Mr. C. J. Peddle, M.Sc., F.I.C., who will give an account of the development of glasses for optical purposes. The following papers have already been communicated and will, as far as time permits, be dealt with in abstract form: (1) "The Development of various Types of Glass," by Mr. C. J. Peddle, M.Sc., F.I.C.; (2) "A Surface Effect in Glass, probably Caused by Re-heating," by Mr. W. M. Travers, D.Sc., F.R.S.; (3) "The Thermal Expansion of Magnesia-containing Glasses," by Mr. S. English, M.Sc., and Mr. W. E. S. Turner, D.Sc.; (4) "The Optical Properties of some Lime-Soda Glasses," by Mr. J. R. Clarke, M.Sc., and Mr. W. E. S. Turner, D.Sc.; (5) "The Annealing Temperatures of Soda-Lime and Soda-Magnesia Glasses," by Mr. S. English, M.Sc., and Mr. W. E. S. Turner, D.Sc.; (6) "The Durability of Lime-Soda Glasses," by Mr. J. D. Cauwood, M.Sc., Mr. J. R. Clarke, M.Sc., Miss C. M. M. Muirhead, B.Sc., and Mr. W. E. S. Turner, D.Sc.; (7) "The Influence of Lime on the Value of Young's Modulus of Elasticity for the Lime-Soda Glasses," by Mr. J. R. Clarke, M.Sc., and Mr. W. E. S. Turner, D.Sc.; (8) "The Density of Soda-Magnesia Glasses and a Comparison with that of the Soda-Lime Glasses," by Mr. S. English, M.Sc., and Mr. W. E. S. Turner, D.Sc.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, May 20, at 5.30 p.m., Annual General Meeting (Members, Associate Members and Associates only) at the Institution of Civil Engineers, Great George-street, Westminster, S.W., to receive and consider the Accounts for the year ended December 31, 1919, and the Annual Report of the Council, and to elect Auditors.

THE OPTICAL SOCIETY.—Thursday, May 20, at 7.30 p.m., at the Imperial College of Science and Technology, South Kensington. The following papers will be read: "The No. 7 Dial Sight, Mk. II.," by Mr. B. K. Johnson; "A Short High-Power Telescope," by Lieutenant-Colonel Gifford.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 21, at 39, Victoria-street, S.W. 1. Social evening. Recently elected Members specially invited.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 21, at 9 p.m., discourse by Professor J. A. Fleming, D.Sc., F.R.S., M.R.I., on "The Thermionic Valve in Wireless Telegraphy and Telephony." Afternoon Lectures, at 3 p.m.: Tuesday, May 18, Professor Arthur Keith, M.D., LL.D., F.R.S., M.R.I., Fullerian Professor of Physiology, Royal Institution, on "British Ethnology—The Invaders of England" (Lecture IV.); Thursday, May 20, Mr. A. P. Graves, M.A., F.R.S.L., on "Welsh and Irish Folk Song" (with musical illustrations) (Lecture II); Saturday, May 22, Mr. Frederic Harrison, D.C.L., D.Litt., LL.D., on "(2) The Re-action and the Critics of the Positivist School of Thought."

THE INSTITUTION OF GAS ENGINEERS.—Arrangements are being made for the annual general meeting of this Institution to be held in London on June 1, 2 and 3, under the presidency of Sir Dugald Clerk, K.B.E., D.Sc., F.R.S.

THE BRITANNIA WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

(*For Description, see Page* 635.)

FIG. 21. SMITHS' SHOP; SOUTH SIDE WORKS.

FIG. 22. BOILER SHOP; SOUTH SIDE WORKS.

FIG. 23. BOILER FLUE WELDING MACHINE.

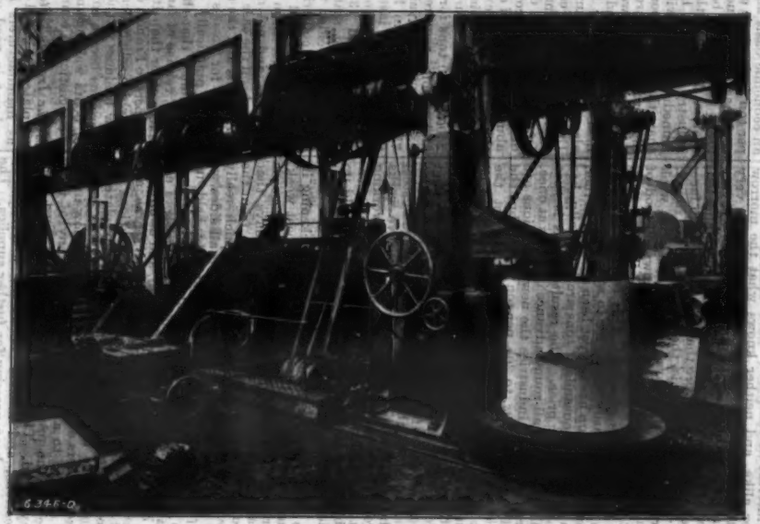


FIG. 24. BOILER-FLUE FLANGING MACHINE.

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(*For Description, see Page* 635.)

FIG. 7. ONE OF THE BAYS OF THE MAIN MACHINE SHOP.

FIG. 8. ONE OF THE BAYS OF THE MAIN MACHINE SHOP.

(*To face page* 638.)

THE BRITANNIA WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

Fig. 9. North Side Works; Boiler Shop.

Fig. 10. North Side Works; Erecting Shop

THE BRITANNIA WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

(*For Description, see Page*,635.)

FIG. 11. STORES FOR SMALL ENGINE FITTINGS.

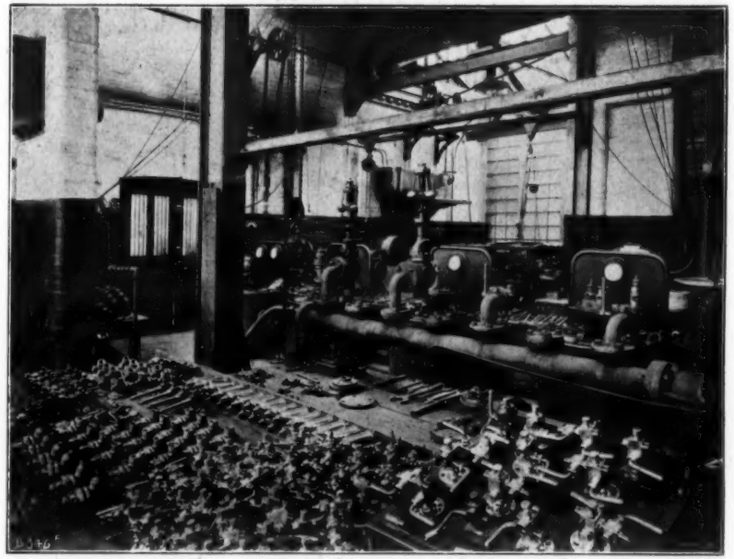

FIG. 12. VALVE TESTING BENCHES.

FIG. 13. PORTABLE ENGINE TESTING PITS.

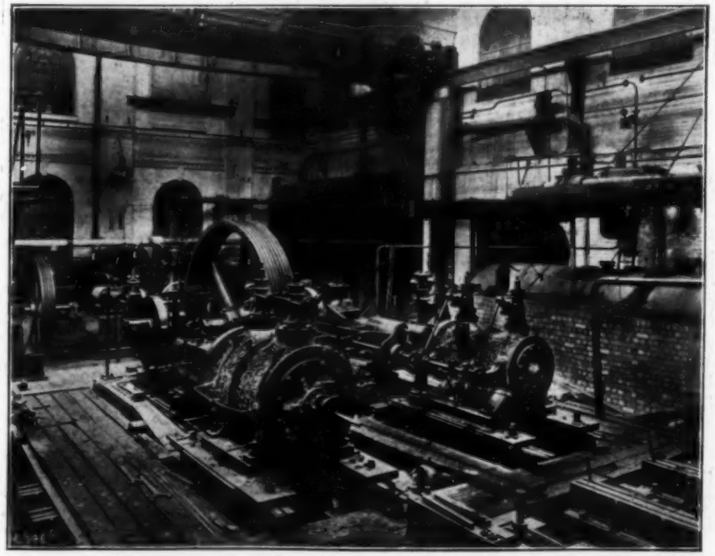

FIG. 14. FIXED ENGINE TESTING BEDS.

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(*For Description, see Page* 635.)

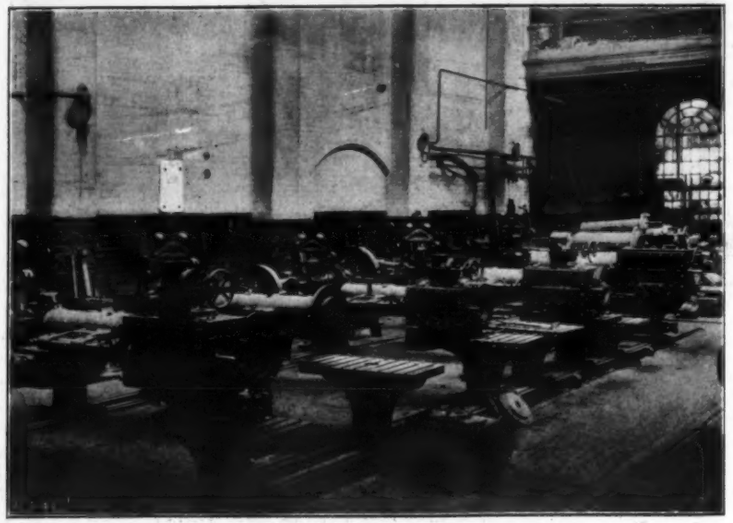

FIG. 15. ERECTING SHOP FOR HORIZONTAL ENGINES.

FIG. 16. THRASHING MACHINE ERECTING SHOP.

FIG. 17. WHEEL FOUNDRY.

FIG. 18. WHEEL SHOP.

(*To face page* 639.)

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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"ENGINEERING" may be ordered from any newsagent in town or country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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TELEPHONE NUMBERS—3643 and 8598 GERRARD.

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With Four One-Page Plates of the BRITANNIA WORKS OF MESSRS. MARSHALL, SONS AND CO., LIMITED, GAINSBOROUGH.

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. So long as postal rates remain as at present there will be no increase in the price of copies sent by inland post, which will continue at 1s. 2d. post free.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 651.

ENGINEERING.

FRIDAY, MAY 14, 1920.

EXAMINATION OF LUBRICATING OILS.

IF the multiple and complex problems of oil testing are to be entrusted to the engineering chemist, as would appear to be reasonable on the whole, then the expert so acting must be proficient in both his professional branches and possess a good knowledge of physics in addition. One expects a great deal of the oil chemist. It is his duty to advise us how to extract the oil or how to produce it by other means, to tell us what the oil consists of, and how it should be treated to yield constituents originally in the oil or to be formed in the course of the treatment to which it is submitted, and how to modify the method of treatment in accordance with the varying demands for special products. He should also understand the preservation and storage of oils. The routine testing of oil is only a part of his duties, which he can, and must, to a certain extent, delegate to assistants. As a consequence, varieties of tests have been worked out and have come into practical use which can hardly yield concordant results when performed by different workers, and are at the best of doubtful value. Hence the growing demand for standard tests. But there is little agreement, so far, as to the co-ordination of the results, and even standardised tests would only supply the inquirer with certain figures or constants without telling him whether or not the oil will answer his particular purpose.

That the Institution of Petroleum Technologists is anxious, in its own interests, to assist in the elucidation of the problems was emphasised by Sir Frederick W. Black, when taking the chair at the meeting on Tuesday, April 20, the second meeting during this session, which the institution devoted to oil examination. In October last Mr. Arnold Philips had discussed "Laboratory Tests of Mineral Oils;"* on April 20, Mr. G. F. Robertshaw, F.C.S., of Manchester, presented a paper on "Methods of Examinations of Lubricating Oils." Standardisation and lubrication are very much to the front at present, and will remain so—on experimental lines in the first instance, we hope. At the October meeting Sir Thomas Holland had expressed the opinion that the experimental work would have to be paid for. Mr. Robertshaw drew attention to the way in which the Society of Leather Trades Chemists in England and the Leather Chemists Association in America deal with their own, likewise complex, standardisation problems. Sectional committees are elected to take up particular lines of research, mostly without expense to the society. To a large extent that has been done also under the general guidance of the Lubrication Committee without restricting the investigator too much as to following up novel lines of research, whilst in the case of paid investigations certain limits have in general to be imposed.

In reviewing the properties and examination of lubricants Mr. Robertshaw distinguished between oils, greases, and special lubricants, classing the oils again as fixed oils and mineral oils purely of the hydrocarbon type. The collective term "fixed oil" is also used to distinguish the non-volatile oils produced by expression or extraction from the volatile essential oils produced by steam distillation. Fats, tallow and lard belong to the fixed oils and are complex organic compounds, either glycerides (i.e., compounds of the salt type of the fatty acids with the alcoholic radicle glycerol or glycerin), or esters (compounds of the oxide type). The glycerides are saponified by the action of alkalis, i.e., split up into glycerin and soaps, salts of the fatty acids; they are also decomposed or hydrolysed by other agents. Free fatty acids may form soap with the metal with which they come in contact, but Wells and Southcombe* have not observed any metal corrosion by the free fatty acids which they add to mineral oils in order to raise the lubricating power. Though few of the fixed oils serve directly and without admixtures as lubricants, some of these enjoy high favour; but castor oil (ricinus) is now being replaced by mineral oils even on aeroplane engines. Rape seed oil shares with other vegetable and animal oils a certain inconstancy in composition and viscosity; yet it still serves as standard liquid for the Redwood viscosimeter. Blown rape oil and other oils oxidised by hot air are used for compounding oils. Greases are partly mixtures of soaps (sodium and calcium) and of refined mineral oil products. The special lubricants comprise pastes wanted for screw cutting, &c., for textiles, leather, &c., and graphite, talc and steatite, &c., used alone or mixed with mineral oils to which they are to impart a fictitious viscosity. Among the new synthetic lubricants developed during the war in Germany Mr. Robertshaw mentioned anthracene oil, which is prepared in thousand of tons.

Many of the properties and tests of these lubricants, important for identification and evaluation, have only an indirect interest for the engineer. Colour matters for the textile manufacturer; density and boiling point are of no importance as such, within certain limits. Surface tension might prove to be all-important, if we could only measure the surface tension between the oil and the metal; what the various methods of determination now in use really signify, we do not understand. The cold test tells us whether the lubricant is apt to thicken or to form a deposit at low temperature; it may be performed by gradual cooling (and rewarming) the stirred oil and by watching the formation (or disappearance) of deposits, or, in the case of turbid oils, in the pour test, by noting when the flow of the oil ceases or recommences. The acidity tests and iodine value indicate liability of the oil to chemical reaction.

The tests of volatility, flash point and gumming are likewise strongly influenced by chemical reactions, and depend hence very much upon the actual experimental conditions. The volatility test (important for internal combustion engines) determines the loss by evaporation at definite temperatures within certain time intervals. Quoting Redcliffe, Mr. Robertshaw did not consider any of the many appliances in use as reliable, though in cases of small loss—and oils of high volatility are hardly lubricants—the Archbutt-Deeley apparatus gave fairly concordant results. Dr. Ormandy added in the discussion the interesting information that German chemists had recently observed greater heat losses when the test was conducted in a nitrogen atmosphere than when performed (as usual) in air or steam, and that he had himself found on continued heating that, whilst the flash point rose as the heat loss decreased, the curve oscillated very strongly. Neither observation is surprising, but they both exemplify the difficulties of the tests. The gumming test (performed with nitro-sulphuric acid, petroleum ether, alcoholic soda, or simply by heating a shallow layer of the oil in air) is clearly one of the tests which cannot generally be standardised for all kinds of oil, and is, perhaps, not much in favour. Dr. Thole mentioned, however, that he had by

* See ENGINEERING, October 31, 1919, page 586, and the discussion on "Lubrication" at the Physical Society, ENGINEERING, December 5, 1919, pages 755 and 758.

* See ENGINEERING, February 6 last, page 186 *ante*.

(To face page 630.)

this test (simple oxidation in air) discriminated between a good and a bad motor-cylinder oil; identical practically as to evaporation, flash point and viscosity, the one of these oils gave 0·4 per cent., and the other 12 per cent. of residue. Both the emulsification tests (necessary in the case of steam turbines particularly) to which Mr. Robertshaw referred, those of Mr. A. Philip and of the Bureau of Standards, have been described in our columns.

There remains the most reliable physical test of lubricants, the viscosity test.* Describing recent modifications of tests in use, including the Michell viscosity meter (see ENGINEERING of April 16 last, p. 509), Mr. Robertshaw recommended the adoption of the poise (the name is taken from Poiseuille) or the centipoise (0·01 poise) as a practical unit of viscosity in absolute measure. The centipoise approximates very nearly to the viscosity of water which is the comparison liquid both of the Engler and the Saybolt viscosimeters, the standard instruments in Germany and the United States. Some unification in this respect is very desirable, and we have stated already that the rape-seed oils, the comparison liquid of the Redwood standard viscosimeter, as now obtainable fluctuates strongly in viscosity. As regards the relation between viscosity and lubricating value Mr. A. Philip remarked that once a certain minimum value of viscosity, necessary to prevent squeezing out of the oil, is exceeded, the high viscosity goes together with low lubricating value; "oiliness" he would simply define as lubricating power, to be measured by friction tests in want of any adequate physical or chemical tests. Mr. Robertshaw had expressed a similar opinion when describing the Thurston machine and showing some blue prints of a large mechanical tester built by Sir W. Bailey and Co. for the Government, and designed for bearing speeds of 10,000 ft. per minute at pressures up to 120 lb. per square inch as well as low speeds of 6,000 ft. at 500 lb. per square inch. Dr. A. E. Dunstan suggested that oiliness like other abnormalities could be traced to unsaturation and to colloidal structure. To Dr. Ormandy the colloidal character of lubricants suggested a possible experimental method of determining the bonding between the metal and the lubricant. When clay (a colloid) was mixed with a small proportion of caustic potash, the clay set and the water filtering off was free of soda; when, however, a potential of 1·6 volt was applied to the paste, soda appeared in the filtrate: thus we had an electric measure of the adsorption of the alkali by the clay. Mr. E. H. Cunningham Craig said that he did not see any difficulty in connecting oiliness with the varying surface energies, probably electric, of the various constituents of the very complex lubricants. When a surface was brought against an oil of that kind, there was a concentration along the solid surface of the particular disperse phase which had a surface energy nearest to that of the solid, followed by the selective concentration of other disperse phases one above the other, until a perfect arrangement preventing internal friction was reached; that was oiliness. Further information on Deely's oiliness test was not given during the discussion, and most people probably advocate standardisation of oil-testing appliances simply to get over the great confusion prevailing, rather than because they have a decided belief in the efficacy of any of them. Our conclusion hence remains that any standardisation, if it is to be really useful, will have to await the outcome of further experimental research.

RAILWAY RATES.

DURING the past week the public inquiry by the Rates Advisory Committee of the Ministry of Transport has been opened. This committee is intended to consider the principles on which the final revision of rates for this country is to be based. The proceedings opened with a statement by Sir George Beharrel, of the Ministry of Transport, who pointed out that it was most difficult at the moment to fix suitable maxima for rates. The principle of maximum rates to which this country has been so long wedded has proved very unfair in the way it has worked out in some cases in recent years. At the present time when the prices of everything are changing from day to day with a general tendency to get higher and higher, it will be found almost impossible to fix maximum rates which will be at all equitable in a few months' time. The retention of the principle is, however, asked for by the Association of British Chambers of Commerce, the Mining Association of Great Britain, the Mansion House Association of Railway and Canal Traffic, the Federation of British Industries, &c.

This reluctance to depart from a system to which the traders have been accustomed for years is natural, but it is quite inconsistent in view of the continual rise in the price of commodities. A merchant sells an article for what he can get for it, and unless, when the cost of labour, &c., goes up, he can raise his price so as to continue to derive some profit for his business, he will cast about for other more satisfactory lines of trade. The railways cannot change their line of business. At the present time the traders have all the business they can handle, and they can meet the demands of labour by increasing prices as they like (except in a few instances) and still get plenty of orders. Why should they be in this favoured position, and at the same time seek to penalise the railways? We are certainly no advocates of giving the railway companies absolute freedom, as regards rates, of the kind which business firms enjoy. The railway service though not actually a monopoly in a small country like this, approaches to it, and some regulation is necessary. The railway companies ask for a system which will enable them to charge a fair rate capable of being varied from time to time with the change of conditions. The past system has fettered them considerably, while the appeal in any rate matter has been wearisome and costly. The endeavour should be made to simplify the system so as to give a reasonable freedom to the companies to conduct their business on profitable lines, and at the same time to provide such ample facilities for appeal against excessive charges that they will be discouraged from abusing the privilege by attempts to take undue advantage of the traders. That, after all, should be sufficient for all who have any regard for fair dealing.

The companies propose that the provision of this character should take the form of, in the first place, local committees composed of representatives of the railway companies and traders, before which cases could be brought with a view to settlement by agreement. In default of an agreement the committee could promulgate a decision, from which there might be appeal to the Railway and Canal Commissioners. Some such inexpensive and expeditious form of procedure is certainly advisable, and this is, we are glad to note, also approved by the chambers of commerce and other bodies. It appears that with these safeguards sufficiently well developed the objections to the abolition of maximum rates should disappear, when greater elasticity would be secured for the future than is possible with any system of maxima, unless off-set by such a factor of safety as would make them at the present time an absurdity.

The future of the railways themselves is obscure enough at the present moment, while who can say anything definite of the country as a whole in the next few months or years? It is palpably absurd to talk about the companies being allowed to make a reasonable profit so as to allow them the enjoyment of such commercial stability as will encourage further development, while at the same time setting a limit to their charges to off-set unknown future quantities in the way of working expenses. Yet it is admitted that they must be allowed this profit—unless solvent, how can they expect to secure fresh capital for development?

Two other points may be mentioned. It has been the custom to base rates on a charge for mileage and a charge for terminal working. There appears to be an opinion that the latter should be abolished in certain cases. It may be pointed out that quite apart from actual unloading and carting, the terminal service always involves the expenses due to marshalling and shunting, and also the use of the expensive land covered by sidings, &c., for which alone the railways are due some compensation by way of charge. Further, this point is also overlooked in the claim made that consignments sent over more than one railway should be charged on the cumulative method as if the journey were on one railway only. This, again, ignores the fact that such journeys usually involve marshalling at junction points on the way, and, therefore, are a greater expense to the railways than through traffic on one line only. This is, therefore, not consistent with the recommendation that the railways may be allowed to run their systems on commercial lines, for this suggests adequate payment for services rendered. What may happen in the future when the grouping system is evolved completely, we are not yet, of course, in a position to discuss.

It is satisfactory to note the traders recommend that once put upon a sound commercial working basis the railways should then be unfettered as far as possible by the State. From this we may judge that on reflection the traders find the pre-war service given by the railways fairly satisfactory, and that as close a return to those ideals is to be encouraged rather than that the country should be plunged into a great scheme of nationalisation from which they would receive very doubtful benefit.

NOTES.

OVERSEAS TRADE COMMISSIONERS.

THE Federation of British Industries Overseas Commissioner Service, which was inaugurated little more than twelve months ago, has made such progress that eight commissioners and sub-commissioners have already been appointed and arrangements made for correspondents in about 15 other countries. In many cases the Federation has been fortunate enough to secure the services of gentlemen already thoroughly conversant with the areas to which they have been appointed, so that their work should speedily result in useful service. In fact, this has already been proved the case in some instances. The object of the organisation is to represent British industries in centres abroad, and by propaganda and intelligence service, &c., foster the interests of British trade. The appointment of Major E. Kennard as Commissioner for the Near East led to a successful British trade exhibition in Athens in October and November, 1919. The visit of the Brazilian Mission last year led to the appointment of a Commissioner for that country. Mr. Montagu Villiers, who is well acquainted with the Scandinavian countries, has been appointed Commissioner with an office at Copenhagen. Mr. C. W. F. Harrison was sent out to South Africa to report on the need for representation in that country, and so on. In addition to these commissioners the Federation draws information from various other sources, including a number of honorary correspondents, who for patriotic reasons, keep it supplied with news of trade openings, conditions, &c. The work should prove of extreme value if run on practical lines. The intention is to watch movements and methods of trade, and to supply information regarding trade requirements and foreign competition, the status of trading firms, &c. It will be possible to put firms in touch with suitable selling agents, interpreters, legal advisers, &c., in the various countries, to make the offices the meeting place for members and agents, &c. It is hoped that as the work of the Federation expands several of the important centres will become self-supporting, and this will enable its activities to be extended to other areas to the gradual encouragement of British commerce throughout the world.

ELECTRIC WELDING IN BUILDING CONSTRUCTION.

The field of application of electric and oxy-acetylene welding is gradually extending. Helped by the war it has established a footing in the shipbuilding industry, and it is quite possible that modern labour conditions may lead to the increase of that footing. In a branch of work which is closely allied to shipbuilding, that of steel building construction, it has not as yet come quite so promi-

* See ENGINEERING, April 19, 1918, page 433 (Dunston and Thole), June 17, 1918, page 655, and September 13, 1918, page 294 (Higgins and Herschel).

nently forward, but this would appear to be a field quite as suitable, if not more suitable, for the application. A start has been made, however, with this class of work in this country, and an all-welded steel roof is now being erected at Brixton. The work is being carried out for Messrs. Stelfast Wheels, Limited, by Messrs. The Welded Construction Company, of 14–16, Cockspur-street, S.W.1. The A.W.P. electric welding process is being employed. The building is situated at 53, Effra-road, Brixton, S.W., and has a ground area of 22,000 sq. ft. The roof is of the weaving-shed type, with 19-ft. spans, and there are a total of 93 trusses in the roof. These are built up as triangular frames, with 4 in. by 4 in. and 4 in. by 3 in. tees, and a 2½ in. by ⅜ in. flat bottom tension member. There is a cross-strut of 2½ in. by 2½ in. tee, and a cross tension bar of 2 in. by ⅜ in. flat. The various members are simply sawn off to length and assembled in a simple jig on the floor. The various joints are then welded on one side, after which the truss is turned over and the other side is dealt with. In some cases one member laps over another and the lap is welded down both edges, in others a butt joint is made, as, for instance, at the connection between the top of the cross-strut and the 4-in. by 4-in. tee, which forms the long slope of the roof. Gusset plates with butt welds are placed in the two bottom corners. The roof is carried by stanchions built up of joists with flat plates welded on top and bottom. The welding lends itself very well to this work, and the stanchions are a very neat job. It should be said that welding is consistently carried out throughout the construction, and that no riveting is used anywhere. Small angle brackets welded to the upper side of the main member carry the purlins, and the trusses themselves are welded by cleats to horizontal joists carried on top of the stanchions. The welding is a simple job, and the method appears a very suitable one for assembly on site, as in this case. The welding up of a truss takes about an hour, and has more than once been done to 50 mins. The total cost of welding a truss, including electrodes used, power and labour, is 9*s.* 4*d.*, and the builders estimate that the method is showing a saving of cost of over 50 per cent. as compared with a drilled and bolted and riveted type of construction.

London Traffic.

Lord Ashfield has a very interesting and well-balanced article in the May issue of *The Nineteenth Century*, discussing the problem of London traffic. It suffers from one defect, namely, that the financial aspect is not dealt with. There is little doubt that, if relieved of this trouble, all the facilities necessary would be forthcoming. The proposed reliefs of special motor roads, and of high-speed tubes, would all assist in getting the crowds in and out of town within the time a person usually is willing to allow for the journey between the home and place of business. Similarly there is much to be said for street widenings to permit of higher sustained speeds for the surface traffic. The trouble is that ultimately all these proposals come down to one of profit and loss, and, if there is little prospect of the former and every probability of the latter, support for the venture will be lacking. This at present appears to us to be the crux of the whole problem, and if we have reached the limit of successful enterprise in this direction, it behoves us to look for relief in others. One such relief—partial, admittedly, but still promising—is decentralisation and the encouragement of towns outside the London circle. Incidentally, Lord Ashfield argues unconsciously in favour of this. While agreeing in a qualified way with decentralisation Lord Ashfield quotes figures to show how street railways are limited as regards passenger capacity. One figure quoted, which is practically double any of the others, refers to passengers booked on the Woodward-avenue cars, Detroit. A note adds: "The extraordinary result of Woodward-avenue, Detroit, is due to a decentralisation of the factories which gives a two-way traffic." This is what we all want. The "satellite" towns go rather further in their ideal, which is admittedly a healthy one, but even decentralisation sufficient to result in traffic in more than one direction would help us in London. This can only be secured by getting places of business settled towards the outer edges. We are with Lord Ashfield all the way when he says that what is wanted is a broad survey of London, with the reservation incidentally of belts of open spaces. We have pleaded on several occasions for the wider aspect, and whether the final solution is to be outside towns or zonal planning, steps should be taken to co-ordinate the work of the sundry bodies each now pushing its own pet scheme, from the London County Council downwards. A transport scheme ahead of development is, in these days when we are so behindhand, rather optimistic, but it is well to have an ideal to aim at. As might be expected, Lord Ashfield is in favour of private ownership, subject to public control. As he points out, a public body itself interested in transport cannot be free from bias. We agree that the controversies are such that only men of goodwill can hope to get any distance towards their solution, and it is high time that the problem should be considered in its broadest sense. At present we have people building at various places—others are discussing transport. Before the question will be solved all these must come together, and work together instead of each putting up requirements for someone to fulfil, without regard to their feasibility or advisability.

The Electro-Deposition of Iron for Machinery Repairs.

The advantage in many cases of being able to add some extra material to a worn machinery part is obvious. In general, of course, such wear as cannot be compensated for by adjustments is dealt with by the replacement of parts, bushing, &c., but there is much attraction in the idea of taking, say, a worn spindle and building it up to its original size by depositing new metal on to it. A considerable amount of work of this kind was carried out at the Third Heavy Repair Shop during the war in connection with the overhaul of motor vehicles. The work was concerned with the deposition of iron on iron or steel parts, and such details as worn stub axle arms, change-speed lever shafts, the insides of wheel hubs, were built up to their unworn size. An important feature of the work was that the coating of iron was deposited directly on the work without any previous copper plating. This feature of the matter is of the first importance in connection with parts which have to be case-hardened or otherwise heat-treated after building up. It may be said at once that from this point of view the work carried out was most successful and that micro-sections of parts on which metal was deposited and which were afterwards heat-treated and carbonised showed that the carbon penetrated through the deposit into the original steel and obliterated the dividing line. A good account of the work which was carried out was given in a paper by Mr. B. H. Thomas which was read before the Institution of Automobile Engineers on the 12th inst. Mr. Thomas pointed out that, as will be very evident, the cleaning and preparation of the work prior to deposition is of the highest importance. The method employed was first to clean the part in petrol, boil for 12 hours, or so, in a caustic soda solution, and clean with scratch brushes. The parts were then made the cathode in a second soda bath, at room temperature, using a sheet iron anode. They remained in this bath for about 3 minutes, and were then washed in running water and treated as an anode in a final 25 per cent. sulphuric acid bath for several minutes. When extra firm adhesion of the coating was required the parts were given a dip in a 50 per cent. nitric acid bath before the final sulphuric acid bath. This was to erode the surface and give a better interlock between the body of the work and the deposit. The deposition was carried out in a ferrous ammonium sulphate solution which was kept as nearly as possible neutral. The anode was made of Swedish iron wire wound into the form of a woven cylinder so as to surround, as far as possible, the work. It was attached to a rocker arm and kept in motion and carried two celluloid cones which maintained a pumping action. The idea of these arrangements was to avoid having a stagnant solution in contact with the work and to keep the ferrous carbonate, which was added to the bath, in suspension. This latter material was added to prevent the solution from becoming acid. The current density worked at was 0·1 amperes per 30 sq. centimetres, and the rate of deposition was a thickness of 0·005 mm. per hour. It was found very important that the current should be kept steady and that the temperature of the bath should not fall below 68 deg. F. It is evident from Mr. Thomas's paper that much care in connection with attention to detail is necessary if work of this kind is to be successful. It is also evident, however, that much useful work was done and the method would appear worthy of further attention.

FRENCH AND ITALIAN HYDRO-AEROPLANES AT MONACO.

By C. G. Grey.

Though the Hydro-Aeroplane Meeting at Monaco was something of a failure, when considered as a sporting event, there was much of technical interest to be seen there by those interested in the design and construction of aircraft rather than in their performances in competition. Unfortunately the only British entrant, a Fairey seaplane, had to be scratched owing to the pilot being called away from England before the machine could start. As a result only French and Italian machines put in an appearance, and, though these were undoubtedly inferior to the best British hydro-aeroplanes as sea-going aircraft, most of them had interesting points about them, which points were either suggestive of methods for the improvement of machines or were excellent warnings of what to avoid.

For purposes of discussion it seems better to divide the machines into float-seaplanes and flying-boats than into speed-machines and long-distance machines, though the competitions were, in fact, arranged on the latter plan. The great event of the meeting was the voyage from Monaco to Ajaccio, thence to Bizerta in Africa, on to Sousse returning *viâ* Tunis to the starting point, a distance of 2,000 km. (about 1,250 miles) divided into three stages, each about equivalent to the daily patrol of any of our North Sea aircraft during the war. The speed races, of which there were two, were each over a distance of about 80 km. (roughly 50 miles), from Monaco to Cannes and back. There were also competitions for high flying. We give illustrations on page 656 and 657 of the more interesting machines.

There were, in fact, only three float-seaplanes among the competitors, a Spad-Herbemont, built by the famous Bleriot firm, a Nieuport, and a Caudron. The Spad, however, played a dual part, in that it had two sets of wings, one for speed and one for altitude. Both were of interest.

The altitude wings were designed by M. Herbemont for war purposes to give the pilot a better view than is usual in biplanes. With this object the upper plane is back-swept from the centre to the tips, or has a "backward arrow" as the French call it, so that the pilot, when looking forward and upward, has a good view past the outer portions of the wings. The lower plane, on the contrary, has a "forward arrow," so that the trailing, or rear edges sweep forward from the sides of the fuselage, thus giving the pilot good vision downwards and outwards. Thus the "blind area" is decreased and, at the same time, the centre of pressure of the planes remains about where it would be if planes with ordinary straight edges were fitted. That this arrangement does not decrease the efficiency of the wings is proved by the fact that the machine reached an altitude equal to that of the Nieuport with ordinary wings and the same engine—a 300 h.p. Hispano-Suiza—the said altitude being certainly a record for water-flying craft. The exact figure has not yet been published but it was given (uncorrected) as 6,500 m., or roughly 21,000 ft.

When this machine was to be used for speed, these "reversed arrow" wings were replaced by a smaller set in which the upper plane is about a foot shorter, on either side, than the lower plane, the upper having a slight backward arrow and the lower being practically straight. The lower plane only has ailerons (for lateral balance), but despite the short span of the planes and the considerable moment of inertia of the big floats, the machine seemed to be very easily controllable side-ways.

As regards general construction it is of interest to note that the fuselage is built entirely of ply-wood, and that there is only one interplane strut on each side. The floats present no novel feature, being of the single step type tapering to a horizontal knife-edge at the stern, with turtle-back decks. The struts between the fuselage and the floats appear complicated, but are, in fact, a simple arrangement of steel tubes, of which two pairs (one on each side) form a very strong cruciform support to the outer top edge of each float.

A rather novel detail in this machine is found in the fuselage, which has a streamlined hump on top behind the pilot's head, to reduce air resistance. This hump is, in fact, part of a lid, which can be lifted off the fuselage, leaving an opening which forms a cock-pit for a passenger immediately behind the pilot. Thus, by changing wings and removing the lid, the machine can be transformed from a single-seater racer to a very effective two-seater touring machine.

The Nieuport, illustrated in Fig. 2, above, is also fitted with a 300 h.p. Hispano-Suiza engine, is of the same type as that (if it is not the identical machine) which beat speed and altitude records several times last year, when fitted with wheels instead of floats. Except for its beautifully streamlined ply-wood fuselage it presents few novel features. Its wings are of the usual "stick and wire" construction. The strut arrangements from fuselage to floats suggest doubts as to the strength of the float-attachment, though, in practice, it seems to be sufficiently strong. It will be noticed that the struts run to the centre-lines of the floats where they join two horizontal tubes in such a way that, if the machine alights with lee-way, the floats are prevented from wrenching off solely by the lateral strength of the tubes which join one float to the other.

A novel feature about the machine is the Lamblin radiator, which may be seen under the lower plane, placed centrally with the fuselage. This radiator has been proved to be highly effective. In appearance it resembles a round ship's fender made of woven rope, or rather a lobster-pot. The tests made by the French "Section Technique" prove it to have less head-resistance than any honeycomb or gilled radiator even of the same projected area, and to be a more effective cooler than any of far greater area. By placing it under the fuselage, it receives the full blast of the airscrew slip-stream, and so becomes more and more effective as the engine does more work and increases the velocity of the slip-stream. The Lamblin radiator is probably, to-day, the most popular type in France, but it is very little known in this country.

The Nieuport floats are shorter than those of the Spad and taper to a vertical knife-edge. Consequently the machine is fitted with a bottle-shaped float under the tail to give it "three-point" suspension, if it should tend, when on the water, to tip backwards on to its tail.

The only other float-seaplane which appeared at Monaco, among the competitors, was the three-engined Caudron shown in Fig. 3, annexed. This machine, made by a firm of brothers whose interests were originally more agricultural than aeronautical, is a straightforward attempt to produce a big, powerful vehicle by using easily available parts and material. The engines are three Le Rhones of 110 h.p. each, a type of engine which did excellent work during the war and proved very reliable. Moreover, in these days of surplus stocks, engines of this type can be bought very cheaply. The bracing of the planes and fuselage is all done with the plainest of metal clips, turnbuckles and solid-drawn wire; there are no fancy fittings or attachments, or patent wire or cable. The interplane and float struts are of ordinary steel tubing.

As may be seen from the illustration, one engine is placed in the nose of the fuselage as in any ordinary tractor biplane, and one is placed on each wing driving a tractor-screw. The whole arrangement is extremely simple, and the construction, though of the type called by the French "chicken-coop"—owing to the maze of wires and struts—is quite sound. The machine is very slow in the air, her size being obviously too great for her 330 h.p. or thereabouts, but she was intended to traverse the Mediterranean in comfort and safety, and not to fly fast.

The weakness of the machine proved to be in the floats, which leaked whenever she was taken out for a test flight. The general opinion seemed to be that the floats were cracked by the impact of alighting, but one who has had a good deal of experience of British float-seaplanes with more than one engine has suggested that the leaks were caused by lateral wrenching of the floats when trying to get off the water. With engines on the wings, and particularly with rotary engines, it is practically impossible to get both engines to speed up together. The result is that one engine runs up to its full power first and pulls the machine round sideways, thus trying to wrench the floats off the struts and racking the float structure severely. This racking action was particularly noticeable during the Caudron's efforts at Monaco, and one was not at all surprised when, after two or three flights, the machine was taken back to the Naval Base at St. Raphaël and withdrawn from the competition.

The only other float machine to appear was a Spad belonging to the French Navy, which is illustrated in Fig. 5, on the opposite page, and flew *hors concours*. There were no particularly novel

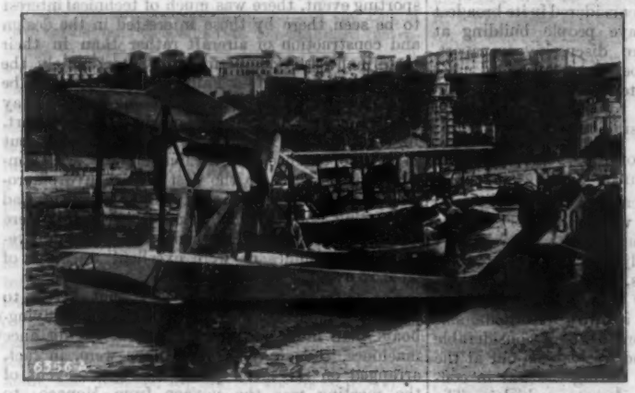


FIG. 1. THE SAVOIA RACER, FITTED WITH 330 H.P. SAN GIORGIO ANSALDO ENGINE.

FIG. 2. THE FRENCH NIEUPORT HYDROPLANE, FITTED WITH LAMBLIN RADIATOR UNDER THE ENGINE.

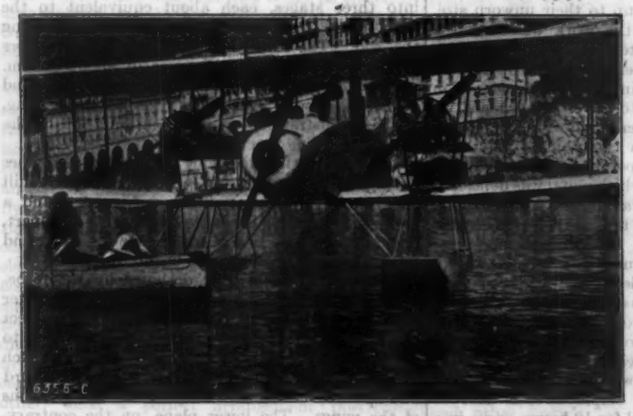


FIG. 3. FRONT VIEW OF THE THREE-ENGINED CAUDRON HYDROPLANE.

FIG. 4. THE TOURING SAVOIA HYDROPLANE AT HER MOORINGS.

features about it as an aeroplane, for it was just a good sound plain job, such as the Spad firm is accustomed to produce. The method of attaching the floats is perhaps worth noting. It is, at any rate, a guarantee against the floats twisting if they hit the water sideways. The most interesting feature about the machine is the gun-fitting. The engine is a 250 h.p. Hispano-Suiza with the cylinders in V and with a geared-down airscrew. This gearing brings the airscrew hub above the engine crankshaft, so that a gun can be laid along the bottom of the cylinder V and arranged to fire through the airscrew hub. As this hub is fairly large it is possible to fit a gun of 37 mm. (about 1½ in.) bore, which fires a shell. Armament of this type was largely used by the French towards the end of the war. The land-going pilots found that case-shot filled with buck-shot were more effective than shell for fighting other aeroplanes, but the Naval pilots carried shell for use against submarines.

Although Fonck, the French "ace of aces," used this case-shot gun in his last 40 victories in the air, the British authorities could never be induced to take the "aero-cannon"—as the French call it—seriously, and adhered rigidly to the old machine-gun.

The flying-boats which appeared at Monaco were particularly interesting by comparison with our British boats, such as the "Felixstowe" types developed by the late Colonel John Porte, the Supermarines and the Gosport boats. It is noticeable that the French and Italian boats have, as a rule, a very low free-board and very straight hulls, and that little effort is made to raise the wings and tail above the water. The reason is obviously that, whereas our boats had to operate during the war in the consistently rough water of the Channel and the North Sea, the French and Italians had the advantage and the fine weather and absence of tide-rips in the Mediterranean and Adriatic. It was natural, therefore, that our gallant Allies should develop boats of a type which strike us as fair-weather craft.

The most notable of the French boats is the Nieuport-Tellier, the hulls of which are built by the famous boat-building firm of Tellier which has, in its time, produced some of the most notable speed-boats, both displacement craft and hydroplanes. One of these boats is illustrated in Fig. 6 above. The aeroplane part of the flying-boat structure is of Nieuport design. The interest of the Nieuport firm in seagoing aircraft is explained by the fact that M. Delage, the chief of the firm, was, before the war, a lieutenant in the French Navy. The most noticeable feature about the Nieuport-Tellier boats is the curious bifurcation of the tail-boom to accommodate the "pusher" airscrew. The extremely tapered hull of the boat evidently made it desirable to devise some method of staying the long rudder-post to enable it, and the hull, to stand the longitudinal strains set up by the elevator; hence this tail-boom, which is peculiar to this make. In all other flying-boats the rudder and elevator stresses are taken by the hull alone. Either the rudder-post is firmly stayed to the hull by a solid pin—as in the Savoia—or else the hull itself is cocked up astern so that the elevator is fixed directly on to it—as in the Felixstowe boats, the Supermarine, F.B.A., George Lévy and others.

Among variants of the Nieuport-Tellier designs it was noticed that the boat used for the trans-Mediterranean competition had a "Matabele" Sunbeam engine of 450 h.p.—one of the two British products at the meeting. Unfortunately, after covering two out of the three stages, the airscrew driven by this engine broke. This breakage apparently damaged the engine, for when a new screw was fitted the engine broke down when a fresh start was attempted. An interesting point about this boat was the fitting of two Lamblin radiators on the deck, just behind the airscrew, where they received the full blast, were easily accessible, and quite out of the way.

FIG. 5. THE SPAD-CANON SEAPLANE.

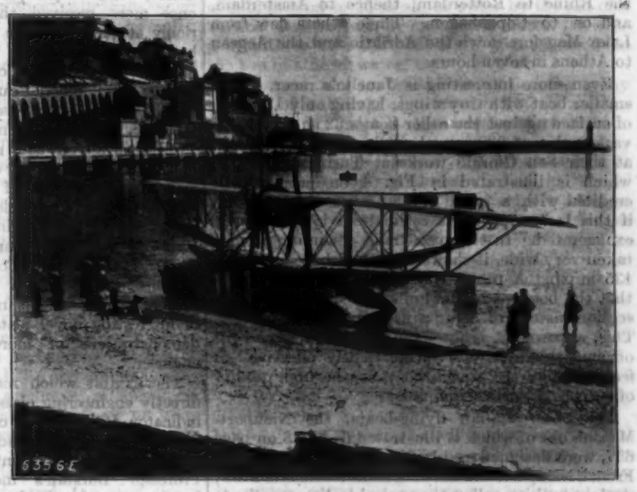


FIG. 6. THE FRENCH NAVAL NIEUPORT-TELLIER HYDROPLANE.

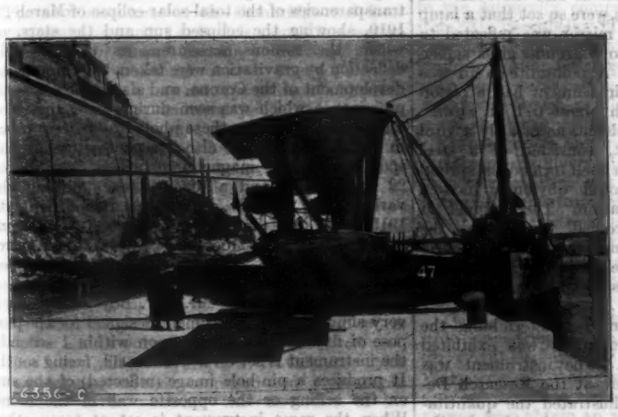


FIG. 7. SIDE VIEW SHOWING THE TANDEM ENGINES OF THE NIEUPORT-TELLIER HYDROPLANE.

FIG. 8. THE NIEUPORT-MACCHI HYDROPLANE WITH ELEVATED ENGINE.

Another Nieuport-Tellier, belonging to the French Navy, and illustrated in Fig. 7, above, has two Hispano-Suiza engines of 250 h.p. each, arranged in tandem, one driving a tractor screw and one a pusher. Judging by the boat's performance with her nominal 500 h.p., the tandem arrangement is not efficient, and this idea seems to be confirmed in practice in all tandem air-screw machines, despite theories and wind-tunnel experiments to the contrary. The majority of the French Navy's Nieuport-Telliers have a single pusher-screw, and a single engine with a honeycomb radiator in front of it in the normal way. Many of these, during the war, have been fitted with Sunbeam engines, which, according to the French Naval aviators, have been very satisfactory; so Great Britain has, after all, some cause for self-congratulation.

The high-speed flying-boats at Monaco were all of Italian design and make. The first to arrive was a type S. 13 Savoia, illustrated in Fig. 4 on page 656, and with a 250 h.p. Isotta-Fraschini

engine. It was flown by Janello, the hero of the ill-fated meeting at Bournemouth last September. This boat, which he uses for touring as most people use a car, is a typical example of the low, straight Italian hull and of the neat Italian engine-housing. The straight hull is obviously conducive to speed in the air, but it seems obvious that a boat so shaped must fly off the water at her flying angle and cannot be coaxed off "rocking-horse" fashion as is done with our boats with their raised sterns. That these Savoias are good flying machines is proved by the voyage of one of the same type from its home on Lake Maggiore, over the Alps and down the Rhine to Rotterdam, thence to Amsterdam, and on to Copenhagen. Three others flew from Lake Maggiore down the Adriatic and the Aegean to Athens in seven hours.

Even more interesting is Janello's racer, a still smaller boat with tiny wings, having only 17 sq. m. of surface against the other boat's 32 sq. m., and a vast engine of 330 h.p., built by the Ansaldo firm at their San Giorgio works at Turin. This boat, which is illustrated in Fig. 4 on page 656, is credited with a speed of 180 miles an hour, and if this is an optimistic estimate it is not greatly exaggerated. In the speed race, including corners taken very wide, it showed an official speed of over 135 m.p.h. A peculiarity of the Savoia design is that the bottoms of the hulls are concave in cross-section instead of being a flat V as is our custom. This, apparently, is intended to give increased lift off smooth water, and is apparently effective. A feature of all the Savoia boats is the high quality of their construction and finish.

The other Italian flying-boats, the Nieuport-Macchi, one of which is illustrated in Fig. 8 on page 657, were designed and built by a firm allied to the French Nieuport, and have the same features of a low, straight hull, as well as the typical Italian excellence of finish. The two at Monaco have noticeable wing structures. In one the wing-cellule, instead of being the usual girder arrangement of struts and wire bracing, is built on the lines of a Warren girder, the interplane struts being at once tension and compression members, the only wire bracing being fore and aft—or incidence bracing, as it is more usually called by aeronautical people. In the other boat the wing structure is more normal, but the engine is mounted in the middle of the upper plane, instead of below it as is customary. The idea is apparently to get a small gap between the planes to match the small chord of the planes and still leave room for the large airscrew needed for the powerful engine. Both these boats are very speedy, one showing a speed of over 138 miles an hour and the other only slightly less.

There is a certain grim humour in the fact that the only machine to complete the Monaco-Bizerta-Soussa and back course was a small George Lévy flying-boat belonging to the French Navy. It is gratifying to know that it had an English engine, a 350 h.p. Sunbeam-Coatalen Cossack, and was piloted (*hors concours*) by a French Naval officer, Ensign Bellot. The only civilian competitor to reach Africa (the Nieuport-Tellier) broke down, as already mentioned. Several other Naval machines started, and stopped on the way. This machine finished the course alone. It is an old boat, used during the war, and it is noticeable that, like our own types, it has the stern of the hull raised well out of the water. The finish is not nearly so good as that of many other boats, but it is soundly built, although it was a tradition in the French Naval Aviation Service that the Lévy hulls were only intended to last six months of regular sea work. A strange commentary on the progress of aviation lies in the fact that M. George Lévy, a banker who started an aircraft factory during the war and built more flying-boats during the last year of the war than did any other French maker, has returned to his financial work and has quite given up building aircraft, so that actually the best performance at the meeting was put up by an obsolete type of machine. One is told, however, that the designer of the Lévy boats is now in the employ of the Nieuport firm, which is apparently making a bid for the premier position among French flying-boat builders. This fact is well worthy of note by British designers and builders of sea-going aeroplanes. On the whole we have little to learn from other nations, but we cannot afford to neglect any opportunity of making ourselves acquainted with what our competitors are doing.

THE ROYAL SOCIETY SOIRÉE.

WHEN the Royal Society Soirées were resumed last year after the war, the collection of novel apparatus and exhibits, though by no means lacking in interest, was perhaps not so large and comprehensive as might have been expected. To a certain extent it may be said that last Wednesday's Soirée, when Sir Joseph J. Thomson, O.M., P.R.S., once more received the guests, was also not so richly stocked as these gatherings had frequently been in pre-war years. The reason is perhaps that exhibitions of scientific apparatus underwent a strong development during the war, and that novelties, whose publication was not desirable at the time, have since been described before meetings. Two lectures were as a rule delivered in the course of the evening on former occasions. This year there was only one subject of a demonstration, but this, which related to wireless telephony, was given twice during the evening by Mr. A. A. Campbell Swinton, F.R.S., in connection with the Marconi Wireless Telegraph Company. We shall refer to this demonstration again at the end of the present article, but meanwhile we begin our notice of interesting novel features with apparatus and demonstrations of more direct interest to the engineer.

The exhibit which most fully came within the directly engineering class was probably the optical indicator for internal combustion engines which was shown by Professor F. W. Burstall. This, we understand, represented the latest form which Professor Burstall's indicator has taken. The arrangement involved two mirrors as in other designs. One mounted above the indicator piston recorded the pressure variations and the other the engine stroke. The mirrors were so set that a lamp beam playing on the first mirror was reflected to the second, and then on to a ground glass screen or a photographic plate. A pointolite lamp was used in the lantern. The instrument had a piston 0·399 in. in diameter with about 0·1 in. stroke. The spring control of the piston, necessarily a vital feature of the instrument, consisted of a steel cantilever arm. The arm in itself formed the spring. It was very stiff, and would obviously have a very short period of vibration. The cylinder of the indicator was water-cooled, as was also the shut-off cock. An oil pump connection was also fitted for lubrication. The indicator had proved satisfactory up to pressures of 600 lbs. per square inch and 2,500 r.p.m.

An interesting instrument for determining the pressure developed by detonators was exhibited by Sir Robert Robertson. The instrument was designed by Mr. H. Quinney at the Research Department, Woolwich. It illustrated the quantitative measurement of the pressure of a blow by the separation of momentum into pressure and time, according to the principle enunciated by Hopkinson. The arrangement consisted of a horizontally suspended steel bar, a short length of which was loose and bore against the main bar with a faced joint. When a blow was applied to the other end of the bar, by the explosion of a detonator, the loose end was thrown off as a result of the application of the pressure of the blow. The momentum of this short length was then measured by catching it in a ballistic pendulum. As the rate of transmission of the impulse on steel was known, the time taken for the pressure wave to pass was known, and the pressure could consequently be deduced.

The Hon. Sir Charles Parsons showed the water-hammer cone which he described in connection with his paper on propeller erosion read before the Institution of Naval Architects last year. An illustration of this apparatus will be found on page 518 of our issue of April 18, 1919. It consisted of a hollow cone fitted with a die cap at the small end through which a hole was bored of the same diameter as the end of the cone. Between the cap and the cone thin metal plates were inserted. The cone was placed in an inverted position in water and allowed to fill. It was then thrust quickly downwards, its bottom end striking a rubber block at the bottom of the water tank. The sudden arrest gave a high rate of relative acceleration to the water in the cone, producing momentarily a cavity at the apex. This, however, immediately closed again with a perceptible metallic hammering sound, and with sufficient pressure, due to the concentrated energy of the closing cavity at the apex, to puncture metal plates 0·03 in. in thickness, indicating a pressure of 140 tons per square inch. It will be remembered that this experiment was worked out by Sir Charles to demonstrate the erosive effect on propellers of collapsing vortex cavities.

An interesting mechanical movement was shown by Mr. A. F. Dufton, in the form of an apparatus for drawing conic sections. The device was able to trace all conics from a circle to a straight line in a single sweep. The curve was described as the polar reciprocal of a circle and the apparatus consisted of a linkage built up of two equal bars hinged at one end and with their other ends hinged to the middle points of another pair of bars. The second pair were hinged at one end and the other ends were constrained to travel along a horizontal line. The pen which traced the conic was carried at the joint of the second pair of bars and the board carrying the paper was pivoted at the corresponding joint of the first pair. This point become the focus of the conic, which was traced by rotating the board carrying the paper. It is not possible adequately to explain the geometry of the construction without a diagram, but it certainly formed a very neat solution of an old mathematical problem. The actual instrument shown was built up with "Meccano" parts, and even with this comparatively rough construction it operated remarkably well and drew true curves.

Astronomical exhibits were not numerous. The Royal Observatory, Greenwich, exhibited four transparencies of the total solar eclipse of March 29, 1919, showing the eclipsed sun and the stars, on which the famous measurements of the light deflection by gravitation were taken, the magnificent development of the Corona, and also the remarkable prominence which was seen during the eclipse and for days afterwards; these photographs were taken in Brazil. There were also five photographs of sun spots and of the magnetic disturbances of March 22 to 25 last, and a diagram exemplifying the variation in latitude during the period 1912 to 1919. The chief interest in the three magnificent photographs of the Moon, sent by the Royal Astronomical Society, lies in the fact that they were taken at Mt. Wilson with the 100-in. telescope.

The neon reflector of Mr. C. V. Boys, F.R.S., is a very simple transit instrument designed for the purpose of finding the correct noon within 1 second; the instrument is set on a window sill, facing south. It produces a pin-hole image (reflected) of the sun on the ceiling or the opposite wall of the room. When the same instrument is set at some other azimuth than due south it can still be used for the determination of time by the aid of an azimuth declination time chart, which is a graphic representation of the hour angle of the sun for all declinations at a particular latitude and azimuth. By means of this chart the hour angle may be read off within 0·1 second of time. The chart included a graphical construction for Bessel's interpolation formula.

The apparatus for showing the existence of a true north-south direction force in the electricity of our atmosphere is a peculiar, simple device which Mr. E. A. Reeves exhibited for the first time. It is merely an electroscope, made up of two pieces of gold-paper (not strips, but pieces about an inch wide) suspended by a fibre of unspun silk within a glass jar, closed by a rubber stopper and varnished with shellac outside and inside for good insulation. This jar is mounted on a tripod in the free open air, only protected from the direct sun light. When the electroscope is charged in the usual way, it will, within 20 minutes or so, come to rest in such a position that the mean plane between the paper foils passes through true north, or oscillates about that position. Mr. Reeves had records of observations made in Hampstead, at Reigate and elsewhere

showing that the north as indicated by this electroscope was generally true within a degree or less; the worst deviation, of 2·5 deg., was observed during the recent magnetic storms. This magnetic storm was also conspicuous in the exhibits of the Meteorological Office, one device of which we mention. Instead of reading the height of a barometer with the aid of a vernier, the observer turns a micrometer head, mounted on the tube, until he sees that the edge of the window of the tubular scale coincides with the top of the mercury column; the micrometer then tells him the required height directly without his having to strain his eyes.

Of the exhibits of the National Physical Laboratory we mention, in the first instance, the wind pressure curves which Dr. T. E. Stanton, F.R.S., has for years been taking at six points on the high-level footway of the Tower Bridge. The curves show that the pressure at any point hardly differs from the average pressure over the whole length of the bridge. The critical angle method of determining refractive indices near 1·52 without the aid of a divided circle which Mr. J. Guild and Dr. J. S. Anderson have worked out, has not yet been mentioned by us. The specimen prism lies on a table between two telescopes (practically in alignment) in front of the source of light, the parallel beam from which is so split up that the one half grazes the one face of the specimen and enters the one telescope, whilst the other half is similarly received in the second telescope, the position of which is adjusted by means of a micrometer; from the small adjustment the index is directly deduced. The device of Dr. W. Rosenhain, F.R.S., and Mr. J. H. Haughton for disclosing the crystal structure of an etched specimen by oriented lustre is very simple. Lamps are placed within a screen of three colours, say, red, green, blue, and are so reflected on to the specimen (plates of lead and aluminium were used) that the light falls obliquely on the surface; the different crystals then stand out in different colours.

The new microtome of the Cambridge and Paul Instrument Company, Limited, is a small instrument designed by Sir Horace Darwin and of the type of the Cambridge rocking microtome. It cuts perfectly flat sections of soft materials (paraffin, celloidin and some non-embedded materials) in steps of 0·001 mm. from 0·001 mm. up to 0·03 mm. in thickness. The specimen is supported on a swinging arm, convenient for cutting and examination; the feed is automatic. The knife is clamped horizontally at both ends, and the inclination of the blade can be altered by a clever device due to Mr. Mason, of the company; the knife rests on a vertical bar, the lower edge of which is cut off obliquely; when a screw bearing against the end of the bar is turned, the bar is raised, and the knife is tilted. The instrument is mounted on a base less than a foot in diameter and is worked by turning a handle.

The X-ray exhibits of Major G. W. C. Kaye, which we recently mentioned, comprised some radiographs of motor tyres, showing the distortion of the rubber and the canvas lining. Another exhibit was a steel block, 2½ in. in thickness, through which the R.D. marking on one side was read quite plainly. These examples were both from Woolwich. The demonstration by Dr. J. C. Mottram and Dr. E. A. Cockayne of the fluorescence of certain lepidoptera (moths of the swallow-tail type, &c.) was made by the aid of a quartz-mercury lamp placed within a box provided with a window of a glass due to R. W. Wood (Baltimore), which is opaque to ordinary light, but transparent to light between $\lambda = 3{,}900$ and 3,100 A.U. It seems strange rather that the fluorescent parts of the wings are of yellow or whitish colour; when the wings are dissolved in glacial acetic acid the solution looks yellow with a greenish fluorescence. Photomicrographs of bacteria, &c., obtained by the aid of ultraviolet light, were shown by Mr. J. E. Barnard; these organisms are sufficiently opaque to ultra-violet rays to be photographed without requiring any previous staining.

The experiments in rotational dynamics made by Mr. Joseph Goold, of Nottingham, and Mr. C. R. Gibson, of Glasgow, are very interesting. Steel bars were set in vibrations by rubbing, the tool being applied either to the horizontal top of the bar, or to the edge. In the first case sand sprinkled on the bars showed the usual nodal lines across the bar; in the second case the sand (which would have settled in a nodal line) was set in rotation, and a watch chain placed on the bar began to wriggle. On the same bars were placed clamps each supporting a steel needle on which a cap rested; the vibrations made the cap spin about its needle. The reason, Mr. Gibson suggests, is that two systems of vibrations are set up which combined lead to elliptical motion. When the cap of one needle was replaced by a flat horseshoe of metal foil, the horseshoe first spun at a certain speed; as the intensity of the vibrations diminished, the speed increased—because the lower partial notes (to use an acoustical analogue) disappear gradually so that the pitch is apparently raised.

Mr. A. Mallock, F.R.S., exhibited an apparatus designed by him for investigating the variation of rigidity of materials with temperature. The specimen (used in the shape of a narrow strip or of a wire) forms part of a torsion balance, which can be lowered into baths of various temperatures (water at 100 deg. or at 15 deg., carbon dioxide, alcohol, liquid air, &c.); the period of vibration changes as the material cools, and this change is recorded on Mr. Mallock's simple chronograph which (as shown) can take 16 electromagnets to record 16 events simultaneously. Of the metals and other materials so far tested by him rubber shows the most remarkable increase (800-fold) in rigidity with cold; this fact, our readers may remember, has been put to use by Sir James Dewar in his thermoscope.*

Mr. G. T. Bennett, F.R.S., exemplified some viscosity phenomena in a simple manner. He placed a glass cylinder containing water on a revolving platform. When sand is previously thrown into the water, the sand is thrown against the wall of the rotating cylinder, of course, but when the cylinder is suddenly stopped, the sand moves inward, and light particles arrange themselves in convergent spirals. This phenomenon is utilised in the Admiralty compasses of Mr. Bennett and Com. C. Campbell. The exhibits of Sir George Greenhill, F.R.S., and Sir George Hadcock were diagrams illustrating algebraical gyroscopic motion; they also displayed a portrait of the Rev. F. Bashforth, the father of the modern ballistic theory, taken at the age of 92 years.

Chemistry was only represented by the synthetic perfumery products—perfumery has practically become synthetic, and that was formerly all of foreign manufacture—of Messrs. J. Crossfield and Sons; and electro-chemistry by the exhibits of the Osmosis Company, Limited, which showed articles of "Osmosed" clay—clay which is purified and graded by electrolysis, a subject to which we shall revert on an early occasion.

The method of mounting panoramic views of wide range, due to Mr. A. R. Hinks, Secretary of the Royal Geographical Society, deserves mention. When several photographs of a mountain range, *e.g.*, are joined so as to form a long flat strip, the viewer may obtain an altogether erroneous impression of the scenery; concave outlines may change into convex. The pictures should be enlarged to an equivalent focal length (say, of 16 in.) greater than the distance of distinct vision and mounted on a polygon circumscribing a circle of radius equal to the focal length. Such suspended photographic polygons look very different from the flat pictures covering our walls.

The model of Mr. R. D. Oldham, F.R.S., illustrating an hypothesis of the origin of mountains, is, at any rate, suggestive. If the variation in density and bulk of the matter underlying mountain ranges be also the cause of the surface elevation, and if the outer crust be possessed of considerable strength and resting on more quickly yielding material, systematic departures from complete equivalence of surface elevation and compensation would result. Mr. Oldham visualised this with the aid of two steel strips so distorted that the movement is strictly controlled in the one strip, while play is permitted in the other; the resistance of the latter to bending gives rise to differences in the surface levels of the two strips. Of geological exhibits we can only notice the very fine photographs of fossil insects from British coal measures, the result of ten years' study of Mr. Herbert Bolton, director of the Geological Museum at Bristol. Some cockroaches—*e.g.*, found in coal from the Forest of Dean, the Kent coal region and from Northern France, help to establish the connection between those coalfields which so far had rested mainly on geo-physical evidence.

The demonstration by Dr. Edwin Edser of the concentration of minerals by froth flotation is not new to our readers. But the similar recovery by flotation of coal from the waste dump is a novelty. Dr. Edser exemplified it by stirring the dust of a very poor coal, containing 53 per cent. of ash, ground to 10-mesh, in water by the aid of a vertical shaft, driven by an electric motor. Within a minute or two the coal froth had collected on the top of a dirty water.

We regret not to be able to notice the many exhibits of a biological character, but should like to mention Professor E. Mellanby's experiments on the effects of vitamines, and the experiments by Mr. Julian Huxley (Oxford) and Mr. Lancelot T. Hogben (Cambridge) on the relation of the thyroid to metamorphosis, and on metamorphic changes induced in the axoloti by iodine; the latter peculiar animal bears gills all its life, but when fed on an iodine diet the gills shrink, and the animal becomes capable of breathing air and of turning into a salamander. Very interesting were also the prehistoric rock engravings which Mr. M. C. Burkitt and Dr. Hallstrym (Stockholm) studied on Lake Onega in Northern Russia, just before the war; they resemble Scandinavian rock engravings which are ascribed to the later bronze age, probably 1200 B.C.

The demonstration of Radiotelephony, to which we have already referred, was given twice in the evening in the meeting room of the Royal Society, in which only the receiving instruments were mounted. The signals and speech received came from the works of Marconi's Wireless Telegraph Company at Chelmsford, the 15-kw. plant of which is provided with an aerial mast 450 ft. high. Showing some of the late Mr. Duddell's oscillation curves of vowels and consonants, Mr. A. Campbell Swinton explained in the course of a brief but exceedingly lucid lecture that the received vibrations were of far too high a frequency to be audible. But if we imagined the crests and valleys of these very rapid vibrations joined by curves, these latter curves (produced by the rectifier) would correspond to vibrations of low frequency and of audible sounds. The receiving apparatus consisted of a loop aerial, simply a wooden frame, 3 ft. square, on which a few turns of wire were wound; a tuning condenser; a set of five triode amplifier valves in cascade, a sixth valve serving as rectifier (this circuit comprising a high tension battery of 50 volts); a double-note amplifier (with a 30-volt battery) and loud-speaking and other telephones to make the sounds audible to the whole room and to individual listeners. The demonstrations were remarkably successful, and of great interest.

* See ENGINEERING, January 23 last, page 122.

ASSOCIATION OF GERMAN INDUSTRIES.—The German Press has paid considerable attention of late to the formation of the above association, particulars of which are forwarded to the Department of Overseas Trade by the British Commercial Commissioner in Cologne. The association was formed in 1919, and has as its purpose the representation and development of the German industries, and the determination of uniform policy of each separate trade, and common action in dealing with labour questions. The association consists of a council and directorate, which latter consists of at least 30, and not more than 60, members who either occupy, or have occupied, a leading position in an industrial undertaking, or have held a position on a Board of Directorate. A Main Committee is nominated, states the *Deutsche Bergwerks Zeitung*, and consists of representatives of each of the 25 industrial branches into which the association is graded. The total number of these representatives is 140, and, in addition, there are 10 representatives of agricultural associations, 10 representatives of home industries, elected by members meeting at the suggestion of the directorate, and 10 representatives of members of the association nominated at the suggestion of the directorate. The Main Committee nominates Special Committees, and elects from year to year a Committee of Investigation. The following Special Committees have been formed: Committee for the carrying out of the Articles of the Peace Treaty; Tax Committee; Economic Committee; Social-Political Committee; Press Committee; Committee of Investigation.

INDUSTRIAL NOTES.

THE claims of the two railway unions for an advance in wages is expected to come before the National Wages Board in about a fortnight. The chairman of this Board is Sir William Mackenzie, and there are four representatives of the railway managers, four of the unions and four of the railway users. In the recent settlement, it was provided that in case of non-settlement by the Central Board of any claim as to pay or conditions of service, no strike could take place until one month after it had been referred to the National Board. The National Union of Railwaymen, it will be remembered, demand a flat rate increase of 1*l.* per week for all conciliation grades other than shopmen. The "Loco." men demand an increase of enginemen's wages from 15*s.* 6*d.* to 1*l.* per day, of those of firemen from 11*s.* 6*d.* to 15*s.* per day, and of those of cleaners from 7*s.* 6*d.* to 10*s.* per day.

Lord Devonport, chairman of the Port of London Authority, and the members of the Joint Committee, comprising representatives of port and dock authorities and the National Transport Workers' Federation, affixed last week in London their signatures to the agreement which gives, with certain small exceptions, a national minimum wage of 16*s.* per day to all dock, port and riverside workers. The standard wage of 16*s.* per day for a 44-hour week will be paid in the principal British ports, 15*s.* in the smaller ports, and either rate at certain intermediate ports. A minimum of 16*s.* per day is guaranteed to piece workers. Supervisory grades receive advances proportionate to those of the men; the overtime rates are increased; no local stoppages of work are to take place; joint port councils are established, and men are paid only when they are actually at work. From Sunday midnight to ordinary starting time on Monday double day rates are to be paid except on perishable work in London, where special rates will be agreed upon locally. The employers will have the benefit of 8 full hours' work per day, waiting time being abolished.

Owing to the increased wages and the additional expenditure involved thereby, it is stated that the Port of London Authority have now raised to 150 per cent. the percentage increase, which previously stood at 85 per cent., on their dock dues, rates and charges on vessels and goods.

The recent moulders' strike, it is reported, has cost the Friendly Society of Ironfounders over 300,000*l.* The society entered the dispute with a quarter of a million; at the close of the struggle all this was disbursed, there being, further, liabilities to the extent of over 50,000*l.*

The annual conference of the Scottish mineworkers held last week at Stirling adopted resolutions to secure a weekly minimum wage of 5*l.* 10*s.* for miners, a fortnight's annual holiday, with pay, and approving of a five-days' working week. A ballot on the matter is to be taken. The conference also requested the fixing of a minimum wage for bringing all workers above "the poverty line." It was stated at the conference that the present normal minimum was 15*s.* per day, or 3*l.* 15*s.* per week.

The conferences in the cotton industry, which have been held since our last reports, came to a close last week by the signing of an agreement, under which the operatives in the spinning and card-room sections receive an advance on standard list rates of 70 per cent., which is equal to 28¼ per cent. on current rates of wages, on and after pay day in the week ending May 15. An extra 10 per cent. will be paid to certain male workers connected with the Card and Blowing Room Amalgamation. The agreement starts on and after pay day in the week ending May 15, and is to remain in force for twelve months. It is countersigned by Sir D. Shackleton, permanent secretary of the Minister of Labour. It will be remembered that the first application of the operatives for an advance of 60 per cent. on current wages was refused, the employers offering Government arbitration. They, later, made an offer of 25 per cent., whilst the operatives said they would compromise at 35 per cent. A further compromise was the result of further negotiations. A day later, the weavers' claim was also settled; they obtain the same advance (70 per cent. on standard lists, equal to 28¼ per cent. on current rates of wages) as the spinners and card-room workers. Overlookers and tapers obtain an advance of 55 per cent. on the standard lists.

A note from the correspondent of *The Times* in New York, given in that journal for last Monday, asks who is responsible for the cost of living, which has risen in America much higher than in Europe. It goes on to state that a wholesale indictment of capitalist profiteers was presented to the Railway Board on behalf of 17 railway brotherhoods and unions by Mr. W. Jett Lauck, who declared that life in America had become so expensive that the working man with a family of five could not possibly exist decently unless he was granted a minimum income of 500*l.* a year. Taking a number of industries, Mr. Lauck produced figures illustrating his contention that higher wages accounted for only a small percentage of the higher prices charged for commodities to the consumer. The state of affairs was now such, he said, that the absolute minimum of 500*l.* a year which the railway workers demanded was barely sufficient to enable a working man's family of five to exist "even in decent poverty."

Last Monday the National Federation of General Workers, in accordance with agreements in connection with the engineering and foundry, shipbuilding and ship repairing, and chemical trades, sent the following four-monthly wages applications to the Employers' Association for hearing before the Industrial Court in June:—"An advance in wages rates existing as on 1st June next to general workers, both men and women, as follows: Adults, 21 years and over, 1*l.* a week; juniors under 18 years of age, 10*s.* per week; piece-workers, an equivalent percentage increase on piece prices. Workers 18 years of age and under 21 who are doing adult work, to receive adult pay." In connection with the railway shopmen and other workers, similar four-monthly wages applications were put forward. An application on behalf of women is being forwarded in connection with the engineering and foundry and shipbuilding and ship repairing trades:—10*s.* for adults and 5*s.* for juniors respectively, as from the first full pay day following March 31, 1920.

A meeting of delegates, called by the Union Executive, and representing the railway workshop members of the N.U.R., was held last Tuesday, at Unity House, to deal with the question of the direct representation of the shopmen in negotiations with the employers. The Executive proposed that shop stewards' organisations should be formed, with departmental committees, and general works committees in the larger centres to deal directly with grievances. It was also suggested that when an organisation was unable to effect a settlement, the point in dispute be referred to a Local Committee, and should the latter be unsuccessful in dealing with the matter, a National Committee formed of representatives of the companies and of the shopmen should arbitrate.

Last Tuesday, Lords Findlay, Cave, Dunedin, Atkinson and Moulton allowed an appeal from a decision of the Second Division of the Court of Session in Scotland. The case raised questions in relation to miners' wages depending on the amount of mineral obtained, the point being whether or not certain deductions, made by the Coltness Iron Company from the wages of a man were legal. The parties agreed to regard the present action as a test case. The man brought an action in the Scottish Courts, claiming 6*l.* 17*s.* 2*d.*, as due to him for a certain period on the ground that the employers were not entitled to make deductions on the gross weight of mineral won by him, on account of an admixture of stones, dirt, &c. The Second Division of the Court of Session in Scotland gave judgment in favour of the man, and the company appealed to the House of Lords. Last Tuesday their Lordships unanimously allowed the company's appeal and ordered that the man's action "be dismissed with costs here and below."

CONTRACTS.—The North-Eastern Railway Company have placed an important repeat order for 25 six-coupled, side-tank locomotives with Messrs. Armstrong, Whitworth and Co. One of the first orders for locomotives received by the firm was for 50 eight-coupled goods engines and tenders from the North-Eastern Railway Company, and although the conversion of Scotswood Works from munition making to locomotive construction was carried out simultaneously with the building of these engines, the progress was such that, within a year of the armistice, the first engine was completed and delivered.

IMPERIAL MOTOR TRANSPORT COUNCIL.—The Right Hon. Sir Eric Geddes, G.C.B., G.B.E., M.P., Minister of Transport, has consented to become a vice-president of the Imperial Motor Transport Council, and has nominated Sir Henry P. Maybury, K.C.M.G., C.B., Director-General of the Roads Department of the Ministry of Transport, to membership of the council. The following nominations to membership of the council have been made by the War Department: Major-General Sir E. E. Carter, K.C.M.G., C.B., M.V.O., Director of Supplies and Transport; Brevet Lieutenant-Colonel M. S. Brander, R.A.S.C.; Lieutenant-Colonel T. M. Hutchinson, D.S.O., O.B.E., R.A.S.C., Chief Inspector of Mechanical Transport; Major Stenson-Cooke, secretary of the Automobile Association and Motor Union, and Mr. H. Percy Boulnois, M.Inst.C.E., chairman of the Roads Improvement Association, have been elected members of the council.

"THE CAMMELLAIRD-FULLAGAR ENGINE."

TO THE EDITOR OF ENGINEERING.

SIR,—The following are three examples of "well-considered" criticism from Mr. Everett's letters.

1. Two quotations in chronological order are "cannot use water for piston cooling" and "of course the lower piston can be cooled by any of the well-known methods." My letter was written to bring about this obvious correction in his views.

2. Now that he knows how opposed piston engines are supercharged he dismisses the system as "utterly inefficient and undesirable," and gives no proof for this statement for the simple reason that none is possible.

3. He says that the Sulzer "design can supercharge without the addition of any gear" and that it is a "controlled port design." There must therefore be added gear in the form of mechanically-operated valves in the supercharging port which are not required in the automatic charging systems as exemplified in the cases of the two-cycle hot-bulb and opposed piston engines, which is the point at issue.

I hope Mr. Everett is not surprised to learn that I am aware of the gladless pressure jet system of piston cooling. Further, it will add to his stock of oil-engine knowledge to learn that this system was first used on some vertical gas engines built, I believe, by the famous firm of Messrs. Willans and Robinson, at least fifteen years ago, and the Sulzer looks like an adaptation of British practice. In view of this early use of substantially the same gear, the idea can, *mutatis mutandis*, be used by any firm with perfect freedom.

Experience and calculation show that for all ranges of supercharge the opposed piston engine is easily the most efficient. Mean pressures up to 200 lb. per square inch have been obtained, and fuel consumptions as low as 0·36 lb. per brake horse-power per hour have been recorded.

Any steps that can be taken to prevent our engineering shops from becoming duplicating factories for engines of Continental design should be welcomed. We want to put the oil engine where Sir Charles Parsons has put the steam turbine, and it will be a curious coincidence if the pioneer work done by Mr. Fullagar at Newcastle proves to be the principal stepping stone to this result.

Yours truly,

L. A. LEITCH.

3, Caledonia Buildings, Clydebank, May 8, 1920.

THE WIRELESS SOCIETY OF LONDON.—At a meeting of this Wireless Society, held in the Lecture Hall of the Institution of Civil Engineers on April 30, a paper was read on an "Automatic Call Device," by Major Basil Binyon, O.B.E. By means of an aerial which had been erected, Major Binyon was able to give a practical working demonstration of this ingenious piece of mechanism. The next meeting of the society will take place on May 21, at the Institution of Civil Engineers, at 6 p.m. A paper will be read by Mr. Phillip Coursey, B.Sc., entitled "Some Methods of Eliminating Atmospherics in Wireless Reception."

INSTITUTION OF MUNICIPAL AND COUNTY ENGINEERS.—A meeting of this Institution is to be held at Norwich on the 22nd inst. for which a very interesting programme has been arranged. Members will meet at 11.30 a.m. in the Norwich Thorpe Station yard and will proceed to Prince of Wales-road to inspect tools and plant for street tramway construction using the Falk cast weld joint. Subsequently a visit will be made to Mousehold Stone Pits to inspect a Jeffrey wagon loader, and sand and gravel washer and grader. After lunch, for which arrangements are to be made at Mousehold Heath, there will be opportunities of inspecting at work a pull-and-push scarifier, tar-painting with lagged wagons using tar loaded hot at the gas works, grit-distributing machine, a Blondin trench machine and power-driven trench rammer. After this return will be made to Westwick Depot, near the city station (Midland and Great Northern Joint Railway) to inspect vertical spindle pumps for trench drainage and other machines. The meeting concludes with tea in St. Andrew's Hall.

ROYAL AERONAUTICAL SOCIETY.—We understand that the Lilienthal glider, owned by the Royal Aeronautical Society and exhibited for some years at the Royal Scottish Museum, Edinburgh, has now been transferred, on permanent loan, to the Science Museum, South Kensington, at the request of the museum authorities. The glider will take its place in the aeronautical exhibit, which is in process of formation there, for educational purposes, while the Piloher glider will remain at the Edinburgh Museum on permanent loan. We also learn, with regret, that the death is announced of Dr. L. E. Stamm, who did valuable research work in connection with the physiological effects of aviation, and read a paper on the subject before the society in January of last year. Under the auspices of the Scottish Branch of the society, a series of lectures on aero engines was delivered to the students of Glasgow University, by Colonel Bristow, on the 3rd, 4th and 5th inst. General J. D. Cormack presided on each occasion, and the attendance was notably good. The council wish to draw the attention of members and students to the courses of lectures on aerodynamics to be delivered on Wednesdays and Fridays at 5 p.m. at the Imperial College, South Kensington, by Dr. L. Bairstow, who is professor of aerodynamics at the college; they also mention that Sir Richard Glazebrook, the Zaharoff Professor of Aviation, is continuing his series of elementary courses on aviation at the Imperial College.

SLAG CONDITIONS IN OPEN-HEARTH BASIC STEEL-MAKING PRACTICE.*

By JNO. F. WILSON (Frodingham).

INTRODUCTION.

BASIC open-hearth slag may be looked upon as the purifying medium in which certain impurities of the raw materials are collected. It can also, to some extent, be considered as a nuisance; but its uses are many, and it cannot be dispensed with. The output and type of slag made will, to a great extent, decide the output and quality of the steel produced. A study of the process from the point of view of the slag made should therefore cover much useful ground.

In the fluid state, slags cannot contain any "free acids" or "free bases," and can be viewed as a solution of different chemical compounds in one another.† To say that a certain slag, after allowing so much of its various constituents for fluxing, contains so much "free" acid or base, is inaccurate. "Free acids" or "free bases," by themselves, demand higher temperatures to bring them to a molten condition than is usually attained by steel furnace slag.

Much useful information can be obtained by the study of slags in solidified form, and much research work is still required in this direction. It must not be lost sight of, however, that the composition of the slag in the molten state is of the most direct interest to the manufacturer, as it can be studied as a whole as well as in detail. Composition by formula can be usefully applied according to the law of Definite Proportion, and there is reason to believe that certain chemical activities do occur in slags when the composition varies from that indicated by certain formula.

COMPOSITION OF SLAGS.

All slags tend to balance themselves and become chemically inert. The chemical components of a slag and of a heated furnace are always endeavouring to form salts of a neutral character. For instance, a bisilicate slag would demand an acid hearth, whereas a subsilicate slag would require a basic hearth, otherwise the slag would extract acids or bases from the hearth to form a more inert slag.

It may be not improbable that at some point between the two qualities mentioned, an inert stage may be reached, which will be common to both the acid and basic hearths. The slag types obtained in the acid and basic steel-making processes are, however, widely different, and for a research of practical value it should suffice to concentrate on the first inert stage obtainable in the basic process. By the first inert stage is meant the composition at which the slag will be inert and yet contain the highest proportion of acids possible in a normal steel furnace slag. For all practical purposes in steel furnaces and metal mixers this can without much doubt be ascertained, it being the lowest critical viscosity temperature‡ slag obtainable in steel furnace practice. Further particulars of such slags are dealt with under the heading of "Silicate Slags."

From this point and as the slag becomes more basic, the inert condition is attained when the viscosity of the slag reaches the ideal degree; the increase in temperature necessary to attain this condition being due to the higher critical temperature of the more basic slag. The principle underlying the inert condition of a molten slag is, therefore, that the degree of viscosity of the slag be ideal. Campbell§ states: "There is an automatic adjustment to a fixed status which is one of the most wonderful phenomena of chemical physics. The only explanation I can offer is that it is an instance of the general law that all forces tend to work along the lines of least resistance, which, being interpreted for this case, means that a slag will combine with anything that promotes fusibility." By ideal viscosity is meant the degree at which the slag would, in actual furnace practice, be described as between a "thick" and a "thin" slag; the actual consistency may be judged as about that of cream.

When a molten slag departs from its ideal conditions of viscosity certain reactions take place, the influence of which is to bring the condition of the slag back again to the ideal point; for purposes of identification and simplicity, the term used for this influence will be "Balancing Reactions." If, for instance, the viscosity of a slag be lower than the ideal degree, i.e., a "thin" slag, the balancing reactions will, given constant temperature, so change the slag composition that at the prevailing temperature the viscosity of the slag will be brought to the ideal degree. The resultant change in composition may be considered as due to two separate sources, namely:—

(*a*) The reduction from the slag to the metal of such elements as give increased fusibility to the slag. The oxides of iron, manganese, and phosphorus are the most important compounds so reduced.

(*b*) Chemical action with the furnace banks, the outcome of which will be to bring compounds into the slag to make the slag less fusible.

The reaction (*a*) will be the preponderating one should the oxides mentioned be present in the slag in sufficient quantities as to be easily available; if this be not the case, the reaction (*b*) will take place. It is customary in furnace operation to add further bases in the form of lime as a preventive to this latter reaction, and to give a less fusible slag. If the viscosity of the slag be higher than the ideal degree, i.e., a "thick" slag, the balancing reactions, given constant temperature, will so change the slag composition that at the prevailing temperature the viscosity of the slag will again be brought to the ideal degree. The change in slag composition will be brought about by making such oxides as those of iron, manganese, and phosphorus pass from the metal into the slag, so as to give a more easily fusible slag. Provided that the temperature remains constant and not too high, chemical action with the furnace banks will be nil (see later notes on the "Influence of Slag on the Banks of the Furnace"). In actual furnace operation it is customary to assist this balancing reaction by the addition to the slag of such materials as iron scale, manganiferous ores, or fluorspar. As will be shown later, the tendency of a "thick" slag in actual practice is to give increased slag temperature and therefore lower viscosity, and iron oxides are not brought into the slag from the metal if carbon be present.

The influence of temperature on the inert condition of a slag can be taken in conjunction with the influence of viscosity; as has already been stated, any increase in temperature imparts greater fluidity to the slag, and, *vice versa*, any decrease in temperature gives a more viscous slag. With the subsequent influence of the balancing reactions already referred to, the outcome need not for the moment be further enlarged upon.

The subject of slag composition will now be dealt with under the three separate headings, namely—(1) Silicate Slags, (2) Phosphate Slags, (3) Tapping Slags. The method by which the molecular composition is calculated is based on the respective amounts of acid and basic oxygen present in the slags, the basic compounds all being considered as RO bases. The presence of the sesquioxides, alumina and ferric oxide, affect the calculation but little, particularly as average steel furnace slags contain but small proportions of such compounds.

SILICATE SLAGS.

General Notes.—The first slag to be formed in basic open-hearth practice is highly silicious and constitutes the lowest critical viscosity temperature slag that is possible from the materials available. Such slags can be divided into two distinct types, and for purposes of differentiation may be classed as follows:—(1) The Olivine Type, (2) the Mellilite Type. Which type of slag will be formed would seem to be regulated by the proportion of FeO + MnO + MgO to the CaO content of the slag, after due allowance has been made for the formation of lime-phosphorus and sulphur-lime compounds.* The junction point has been given by Juptner† as

$$\frac{\text{Oxygen in FeO + MnO + MgO}}{\text{CaO}} = 0{\cdot}7.$$

When the proportion is above 0·7 the slag is of the Olivine type, and when below of the Mellilite type.

The lowest critical viscosity temperature slag of the Olivine type would seem to be well established in actual furnace practice, such a slag being purely monosilicate. Examples of such slags are given, as they are comparatively easy to obtain by working a metal mixer short of lime, or by using raw dolomite in place of lime, or limestone, in barely sufficient quantities.

The lowest critical viscosity temperature slag of the Mellilite type seems to be more highly acid than the other, the composition being between a monosilicate and a bisilicate, slag, viz.:—

$$2\,R_2SiO_4 + 1\,RSiO_3$$

or, taken as a whole, this would be $R_5Si_3O_{11}$. An example of such a slag is given, but owing to the difficulty in obtaining the lowest critical temperature slag of this type, the author has been unable sufficiently to check this composition with other examples.

Olivine Type Slag.—Examples of the practically pure low critical temperature point monosilicate slags are given in Table I. These slags were taken from a metal mixer of the "active" type. The composition of these slags, by the method given in the foregoing, may be expressed by formula in the proportions as given in Table II. A study of the activities of such slags would seem to prove them to be at what has been termed the first inert point. Practical experience shows that when more bases are added to such purely monosilicate slags, the excess bases quickly combine with further acids from the metal to form further silicates or phosphates.

On the other hand, should more silicon be oxidised from the metal than would make the slag conform to the monosilicate quality, chemical action between the slag and the furnace banks will take place, and provide the necessary bases to bring the slag back again to the pure monosilicate quality. The presence of sufficient phosphoric acid acts as a guard against this latter reaction taking place, as excess silica will replace phosphoric acid present in the slag. It must not be lost sight of, however, that these reactions are not instantaneous, as will be seen by the presence of the small quantities of excess acids as shown in Table II, and this "time lag" is a factor to be considered. (See later notes on "Influence of Slag on the Banks of the Furnace.")

The composition of the slags as given in Table II show these slags to be almost purely monosilicate, and how far this formula is true of the actual slag composition would seem to be well indicated by the crystalline nature of these slags when slowly cooled.

Ladles with a slag-holding capacity of about 10 tons were filled with Nos. 1, 2, and 3 slags, and each ball was allowed to solidify before tipping. The interior of each slag ball, on subsequent examination, proved very interesting, the well-defined and apparently single crystal formation being easily visible to the naked eye. Fig. 1, page 662, is cross-section sketch through the interior of the slag ball. The crystals in the more quickly-chilled outer portion grew inwards in a similar manner to those in the outer portion of a "hot-cast" steel ingot. The crystals in the inner portion were, like those on the outside portion, also columnar, but in this case they grew in all directions. [To save further description the author showed a specimen piece of the slag.]

TABLE I.

	Slag No. 1. Per cent.	Slag. No. 2. Per cent.	Slag. No. 3. Per cent.
SiO_2	34·50	32·72	34·22
CaO	36·03	32·17	26·57
P_2O_5	1·72	4·04	2·02
MnO	8·18	7·05	13·58
MgO	9·95	11·64	15·48
Al_2O_3	1·04	1·25	1·80
FeO	7·29	7·94	3·84
Fe_2O_3	1·36	1·56	0·43
CaS	0·11	0·10	0·06
$CaSO_4$	0·43	0·61	0·47
Total	100·61	99·08	98·47

TABLE II.

	Slag	Slag	Slag
Molecules of calcium phosphate ($Ca_4P_2O_9$)	0·19	0·45	0·23
Molecules of olivine (R_2SiO_4)	8·75	8·30	8·84
Excess acid oxygen	0·72	0·73	0·44

Mellilite Type Slags.—An example of a practically pure low critical temperature slag of this type was taken from a metal mixer of the "active" type:—

Slag No. 4.

SiO_2	CaO	P_2O_5	MnO	MgO	Al_2O_3	FeO	Fe_2O_3	CaS	$CaSO_4$
39·20	37·22	1·79	5·46	5·98	5·57	2·57	2·37	0·29	0·12

The composition of this slag may be expressed by the following formula:—

Molecules of calcium phosphate ($Ca_4P_2O_9$)	= 0·29
Molecules of monosilicate (R_2SiO_4)	= 6·91
Molecules of bisilicate ($RSiO_3$)	= 3·48

The above formula shows two molecules of monosilicate to one of bisilicate. The crystalline nature of the slowly-cooled slag is, like the pure Olivine type mentioned, that of a well-defined and single-crystal type. A specimen piece of the unchilled interior is illustrated in Fig. 1, page 662. These crystals, it will be noted, are tabular.* By taking the silicates of slag No. 4 as being of one type only, the formula for this slag may be expressed as follows:—

Molecules of $Ca_4P_2O_9$	= 0·29
Molecules of $R_5Si_3O_{11}$ or $(RO)_5(SiO_2)_3$	= 3·46
Excess acid oxygen	= 0·02

Other examples of this slag type gave a similar composition, but sufficient work was not done fully to demonstrate the action of the slag on the addition of further acids or bases. That this formula represents the lowest critical temperature of this slag type is, therefore, stated with reserve.

Phosphate Slags.

In their most concentrated form phosphate slags contain no other bases beyond the requisite amounts necessary to form the phosphate, silicate, and sulphur compounds, &c. As can be expected, the silicates in nearly all slags containing appreciable quantities of phosphoric acid will be of the Olivine type, as the lime taken up in the formation of the calcium phosphate will reduce the amount of lime available for the formation of the silicates. The

TABLE III.

	Slag No. 5. Per cent.	Slag No. 6. Per cent.	Slag No. 7. Per cent.
SiO_2	27·00	28·30	28·20
CaO	37·29	38·02	39·06
P_2O_5	7·92	8·06	7·63
MnO	12·10	8·65	9·48
MgO	5·27	6·80	5·10
Al_2O_3	1·00	0·98	1·50
FeO	4·74	7·04	6·40
Fe_2O_3	3·27	0·71	0·99
CaS	0·16	0·21	0·08
$CaSO_4$	0·70	0·53	0·35
Total	99·45	99·30	99·79
Slag Composition.			
Molecules of $Ca_4P_2O_9$	0·89	0·91	0·88
Molecules of R_2SiO_4	7·16	7·06	7·22
Excess acid or basic oxygen	0·09 (basic)	0·90 (acid)	0·51 (acid)

comparative temperatures, as judged in the steel furnace, of phosphate slags in their most concentrated form, and of the low critical temperature silicate slags, make it

* Paper read before the Iron and Steel Institute, May 7, 1920.

† Ledebur 'Handbuch der Eisenhüttenkunde,' 2nd ed., vol. i, p. 175.

‡ Steel furnace slags do not possess a definite melting point, as they gradually soften and become more fluid as the temperature rises. The term "critical viscosity temperature" or "critical temperature," as applied to the slags under discussion, is used to denote the particular temperature required to bring each slag to the ideal condition of viscosity.

§ Campbell, "Manufacture of Iron and Steel, Basic Open-Hearth Process," Section XI A.

* It may be that the aluminates dissolved in the silicates of the slag really act as desulphurisers.

† Journal of the Iron and Steel Institute, 1900, No. II, p. 293.

* These interior crystals must not be confused with the many varieties usually found at the contraction cavities in the centre of masses of cooled slags, as they constitute the whole of the shaded area, as shown in the sketch.

evident that phosphate of lime has a higher molten temperature than the low critical temperature silicates, with the Olivine type given as an instance. This being the case, it is natural that phosphorus can be reduced back into the metal from the slag before the silicon, and that silica is able to replace phosphoric acid present in the slag. The slags given in Table III are highly silicious phosphate slags.

Nos. 5 and 6 slags were made in a basic open-hearth furnace of the tilting type, while No. 7 was the first slag to be formed in a cold-charged fixed basic open-hearth-furnace.

After allowing the necessary bases for the formation of the phosphate, it will be seen that the slags are almost purely monosilicate. At the period when such slags as Nos. 5 and 6 existed in the furnace, phosphorus was generally being reduced from the slag, owing to the gradual lowering of the basicity of the slag by the reduction of iron oxide. For this reason, and by the influence of time lag on the speed of the balancing reactions, it was most generally found that a little excess acid was present.

Such slags can be made with a much higher proportion of phosphate, and examples are given in Table IV. These were taken at random from published communications,* and are slags made at the end of the first period in the Hoesch process.

TABLE IV.

	Slag No. 8.	Slag No. 9.	Slag No. 10.	Slag No. 11.	Slag No. 12.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	11·00	18·00	12·20	11·80	11·40
CaO	41·91	43·00	41·56	45·48	48·86
P_2O_5	23·95	17·00	22·85	22·36	22·13
MnO	6·15	7·75	5·03	4·96	3·93
MgO	7·20	6·00	4·32	4·00	4·00
Al_2O_3	2·10	3·00	1·36	1·38	1·60
FeO	5·95	8·36	10·25	7·06	4·67
S	0·36	0·67	0·07	0·12	0·14
Total	98·62	103·78	97·64	97·16	96·73
Slag Composition.					
Molecules of $Ca_4P_2O_9$ ..	2·70	1·02	2·58	2·52	2·50
,, R_2SiO_4 ..	2·92	4·77	3·24	3·13	3·02
Excess basic oxygen ..	1·89	2·12	0·79	1·51	2·11

The formation of such slags is of economical importance in steel-making. The balance of the slag, after allowing for the formation of the calcium phosphate, is almost purely monosilicate, but unlike the more silicious slags, any excess above this composition is generally due to bases. This can be reasonably expected, as, although the general trend of the balancing reactions will be toward the reduction of phosphoric acid back into the metal, the higher critical slag temperature given by the increased content of calcium phosphate will tend to make the slag basicity higher, owing to this increase in temperature.

The curves shown in Fig. 2 illustrate the working of the Hoesch charge in which slags Nos. 10, 11 and 12 were made, the quantities, and compositions of the slag being calculated from the particulars given in the publication.

As will be discussed later, the slag giving the quickest working speed will be the one having the lowest critical temperature, consequently phosphate slags with the least quantity of "excess" bases will not only have a higher commercial value through greater concentration of the phosphates, but will promote more speedy working. Independently of this, and without discussing the many interesting theories of phosphate solubility, it is a well-known fact that the higher the slag temperature the greater will be the percentage of the more insoluble phosphates. Should lime be available in such proportions as to prohibit the formation of silicates of the Olivine type, subsilicates as well as monosilicates will probably be formed, the proportions varying with the slag temperature.

TAPPING SLAGS.

The composition of tapping slags should be such that the purification of the steel is brought to a satisfactory degree and a sufficiently high temperature; also that this be done in the most economical manner, and by the least expenditure of bases. So far as the author is aware, the most basic silicates formed in these slags are monosilicate (R_2SiO_4) in the Olivine type slag and subsilicates (R_3SiO_5) in the other. Since it is impossible that "free" acids or "free" bases can exist in a molten slag, any bases present in the slag over and above the quantities represented by the above formulas (and allowing for the formation of phosphates and sulphur compounds, &c.) must exist in some—probably unknown—combination. Tapping slags are not passive, but exert certain forces to extract from the metal such elements as phosphorus and sulphur. "Active" bases must therefore be present in addition to those passive bases satisfying the silica, phosphoric acid, &c., at the prevailing temperature; and these bases, when brought into contact with acids from the metal, must not only be capable of forming compounds similar to those already present in the slag, but the combinations in which these "active" bases exist must be such that they will be molten at the prevailing temperature. As has already been stated, the probability is that monosilicate is the most basic silicate that can be formed in a slag of the Olivine type and subsilicate in that of the other type. If this were not the case, and if more basic silicates or phosphates were formed according to such formulas as R_4SiO_6 or even R_2SiO_7, &c., it would be natural to expect that such compounds would demand a greatly increased molten slag temperature. The reverse is sometimes actually found to be the case, especially in the case of high ferruginous slags, and it would seem probable that when the available acids are satisfied at the prevailing temperature bases will unite with bases.

We know that by mixing one base with another a lower critical temperature can be obtained than with either of the bases by themselves; the formation of "active" base compounds from the excess bases present in slags may owe their formation to this fluxing property, and the temperature at which they can be dissolved in the slags will depend upon the fluxing power of the different bases with each other. The bases present in the slag which have the greatest fluxing power would most probably be those forming the "active" bases mentioned. In support of this theory the following notes may be given:

Iron Oxide.—Early laboratory tests with electric furnaces have shown that iron oxide will combine with lime. The probability is that iron oxide, relative to

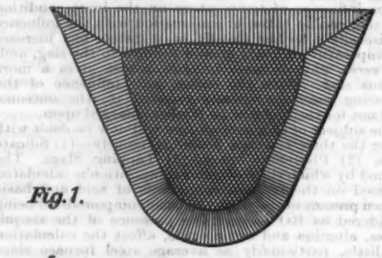
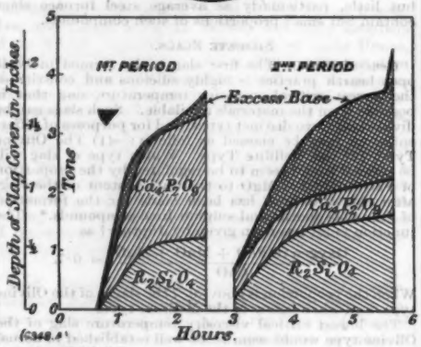
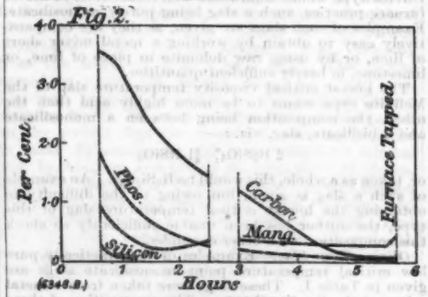


Fig. 1.



(5348.)

Fig. 2.



(5348.B.)

lime, can act as an acid,* and in steel furnace practice can act as such at comparatively low furnace temperatures. It is a fact that the addition of iron oxide reduces the melting temperature of basic steel furnace slags, it being common practice to obtain greater slag fluidity in this manner. (See notes on "Balancing Reactions.")

Oxide of Manganese.—The effect of this compound on the fluidity† of the slag seems to be similar to that of iron oxide. The amount available from the raw metal is, however, limited; and it is sometimes added to the slag, both for its mixing value and its action as a desulphuriser.

Alumina can be looked upon either as a weak base or a very weak acid; in a molten slag, and at steel furnace temperatures, it could not be considered strictly as a neutral. From its dual action it should be reasonable to assume that until the most basic silicate has been formed it will act as a base, and only after this as an acid. To its apparently low fluxing power may be attributed some of the difficulties in metallurgical operations, when the alumina content of the slag is high. Its value as an "active" base is probably unimportant, although it has been suggested that, as the desulphurising power of a slag cannot be expressed simply in terms of its calcium oxide percentage, it may act as a desulphurising agent.‡

In Table V analyses are given of tapping slags with their corresponding composition by formula.

TABLE V.

	Slag No. 14.	Slag No. 15.	Slag No. 16.	Slag No. 17.	Slag No. 18
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	17·70	9·45	17·70	13·20	12·40
CaO	52·50	51·24	54·70	40·13	46·28
P_2O_5	4·90	6·68	7·28	7·47	5·00
MnO	5·02	5·02	2·60	10·90	10·25
MgO	9·24	6·72	5·29	7·50	5·92
Al_2O_3	1·17	1·20	1·70	2·99	1·90
FeO	7·20	10·16	5·12	18·10	17·03
Fe_2O_3	1·42	8·80	3·55	—	—
S	0·34	0·26	0·20	0·44	—
Total	99·49	99·53	98·12	100·73	98·78
Slag Composition.					
Molecules of $Ca_4P_2O_9$ ..	0·55	0·75	0·82	0·85	0·56
,, R_2SiO_4 ..	4·69	2·50	4·69	—	—
,, R_3SiO_4 ..	—	—	—	3·50	3·28
Excess RO bases	6·64	13·30	3·92	12·86	13·64

Nos. 14 and 15 slags may be compared together, as they were both made with high carbon steels, and in similar furnaces. The steel made with No. 15 slag was of a higher degree of purity than in the other case, and when tapping the charge from the furnace containing No. 14 slag, some of the phosphoric acid was reduced from the slag into the metal. As far as could be judged, the critical slag temperature was highest in the case of No. 14; it was undoubtedly at a high temperature for the longest period. Slag No. 16 was from a slowly worked charge of mild steel. Slags Nos. 17 and 18 were also from mild steel charges, but in these cases the silicates would be of the monosilicate Olivine type. The degree of basicity of each of these slags, and the number of molecules of excess base expressed as RO in the formula, will be noted and compared. If, in conjunction with this, an estimate is made as to the probable quantity and quality of "active" base compounds formed, some idea of the economic value of each of the slags can be obtained.

INFLUENCE OF SLAG VOLUME.

The principal methods of manufacturing steel in the basic open-hearth furnace give, in one way or another, a decrease in the depth of slag covering the metal bath; they may be stated as follows:

(*a*) By the addition of varying proportions of steel scrap to the metal charge, and so reducing the quantity of slag-forming elements in the charge.

(*b*) By the employment of the "active" type of metal mixer, and preliminary removal of a portion of the slag-forming elements in the raw iron.

(*c*) By removing a portion of the slag from the steel furnace, by promoting a "foamy" reaction towards the end of the exothermic reaction period. The "foamy" and unfortunately ferruginous slag, escapes in varying quantities through a suitable slag notch.

(*d*) In the Bertrand-Theil and Hoesch processes, the slag removal is complete to within 25 per cent. of the whole at the end of the exothermic reaction period.

(*e*) By the use of a tilting type of furnace which allows of a portion of the slag being easily removed through the slag notch.

(*f*) As in the Talbot process where also per ton of raw iron the bath area is increased; this effect being to reduce the depth of slag covering the surface of the metal.

(*g*) By increasing the furnace bath area, and

(*h*) By skimming the slag off the metal bath by means of a suitable blast.

The deleterious effect of high slag volume on the speed of production may be expressed as follows:

1. The slag, being a very poor conductor of heat, retards the speed of heat transmission between the furnace flame and metal bath.

2. The greater the depth of slag cover, the greater will be the blanketting effect of the slag on the metal. This "smothering" action of the slag suppresses the carbon boil, and a high slag volume will therefore give slow carbon elimination.

3. The more rapid the carbon boil, the more will the slag be agitated. In this manner the superheated slag surface becomes mixed with the lower and cooler portions, and the transmission of heat is thereby aided. This action is important also in the way it affects furnace wear and tear, and will be considered later under a different heading.

The lowest depth of slag possible to work with will give the best working conditions with regard to:

1. Rapid heat transmission from flame to metal.
2. Low blanketting effect.
3. Low slag surface superheat.

The effect of these three items on steel furnace practice is important, and the amount of slag carried in the furnace is worthy of every consideration. Undoubtedly, the amount usually carried is more than the minimum amount necessary, it even often pays to reduce the small quantities usually present in acid open-hearth practice. The degree of slag removal, the period at which it is removed, and the time taken to remove it, are important factors, and may more than counterbalance the increased working speed to be obtained by using a smaller volume of slag.

INFLUENCE OF SLAG VISCOSITY ON SPEED OF PRODUCTION.

The higher the slag viscosity, the greater will be the blanketting effect of the slag upon the metal, and the slower the speed of carbon elimination. Owing to this,

* For Nos. 8 and 9 see "The Relative Economy of Basic Bessemer and Basic Open-Hearth Processes," by Schock, *Stahl und Eisen*, 1913. For Nos. 10, 11, and 12 see "The Hoesch Process," by Petersen, *ibid.*, 1910.

* Stead and Ridsdale, "Basic Slag," Journal of the Iron and Steel Institute, 1887, No. 1.

† Campbell, "Manufacture and Properties of Iron and Steel," Section XI. A.

‡ Field and Royster, U.S. Bureau of Mines, 1918. Technical Paper, No. 189.

and in a similar manner to the effect of high slag volume, the greater will be the tendency towards a highly superheated slag surface. More viscous slags will, like high slag volume, therefore give a slower furnace working speed.

An example of the increased blanketting effect of more viscous slags can be clearly illustrated by adding burnt lime to the furnace bath during the boiling down period; the speed of carbon elimination rapidly decreases as the slag becomes more viscous.

Influence of Slag Volume and Viscosity on the Quality of Steel Produced.

The soundness of the finished steel, apart from slag composition, and the presence of such elements as carbon, silicon, sulphur, phosphorus, and manganese in the metal, will depend greatly upon the temperature and the degree of deoxidation of the steel before tapping. The higher the metal temperature the greater is the affinity of the carbon in it for oxygen; but should the volume or viscosity of the slag be such as to increase the blanketting effect, the result will be to restrain the carbon reaction and retain oxygen in combination with the steel. The lower the volume and viscosity of the slag on the metal surface, the greater will be the purity of the steel with regard to oxygen. A restrained carbon reaction owing to high slag volume means, however, that the temperature of the metal bath can be more quickly raised to the degree required for tapping, but, as will be pointed out later, low slag volumes permit of higher flame temperatures, so much so indeed that the temperature of the metal can be raised more quickly by high flame temperature and low slag volume, than by a lower flame temperature and a higher slag volume.

The Influence of Slag Condition on the Oxidation of the Metalloids.

The oxidation of the silicon, phosphorus, and manganese from the iron gives exothermic reactions, and all these reactions proceed at the lower temperatures and in earlier periods of the charge. Given the required oxygen for the oxidation of these elements, the condition of the slag will have no direct influence on these reactions taking place: indirectly the volume and viscosity of the slag will have some influence owing to their effect on the conduction of heat from the flame to the metal bath. The heat-raising effect of these reactions is, however, progressive, and this influence should not be of any great importance.

On the other hand, the volume and viscosity of the slag greatly influences the endothermic and high temperature carbon reaction. This influence is one of the most important in steel-making, and is one of the chief factors in deciding the efficiency of any steel furnace practice. As stated, carbon oxidation gives a strongly endothermic reaction, and therefore proceeds with an absorption of heat, and this reaction is limited to the higher temperatures in steel-making.

Given the required oxygen available for the oxidation of the carbon, the speed of carbon reduction will be in proportion to the speed of the transmission of heat from the furnace flame to the metal. The greatest speed of production will, therefore, be obtained by: (1) High flame temperature; (2) Low depth of slag cover; (3) Low degree of slag viscosity.

An example (see *ante*, page 662) has been given which illustrates the blanketting effect on the carbon reaction by increasing the slag viscosity; and the relative effect of slag volume as compared to viscosity can be estimated for this particular reaction. It should be reasonable to expect, therefore, that the control of carbon oxidation will be quite as sensitive by increasing the slag viscosity as with a higher slag volume, and all the more so when it is considered that the oxygen held by the metal under the first-named condition will be less. The raising of the metal bath temperature at the end of the charge to the degree required for tapping should be as quickly obtained by regulating the viscosity of a low slag volume as when more slag is carried.

The Influence of Slag Volume and Viscosity on the Working Temperature of the Furnace.

By furnace working temperature is meant the temperature of the roof, linings, and blocks of a furnace throughout the working of a charge. The higher the furnace working temperature the greater will be the wear and tear on the furnace brickwork, and the shorter the life. In practice, this temperature is not altogether dependent on the calorific intensity of the flame. Indeed the reverse is sometimes actually the case.

The heat transmitted to the molten bath, whether by conduction, radiation, or convection, varies as the difference in temperature between the heating body and the slag surface. The slag surface superheat will, therefore, directly influence the proportions of the heating value of the fuel that will be transmitted to the molten bath and to the furnace brickwork.

A highly superheated slag surface must give a higher furnace working temperature, while a lower slag surface superheat will lower the furnace working temperature. This influence can be clearly seen during the working of a charge. The influence of slag volume and viscosity on slag surface superheat has already been discussed, and a reason thereby given of why it is possible to get a lower furnace working temperature with a higher flame temperature.

The influence of slag surface superheat on furnace working temperature is illustrated by the graph shown in Fig. 3. Let the curve *a* represent the slag surface temperature during the working of the charge, *b* the temperature with increased slag volume, and *c* the temperature with decreased slag volume. If we assume that at the temperature denoted by the line *d–d* excessive wear and tear on the furnace linings will commence, the distances *x*, *y*, and *z* will denote the period of time at which excessive wear and tear on the furnace brickwork is taking place.

Influence of Slag on the Banks of the Furnace.

A study of steel furnace slags from all points would not be complete without considering their influence on the furnace linings. It should not be necessary in discussing this to give much more than a general outline of the principles involved.

The banks of a furnace may be divided into three separate sections as given hereunder, as the action on each section of the lining should be different: (1) That portion situated above the slag line subject only to attack from fume, &c. (2) That portion of the slag line subject to attack from the slag, and (3) That portion below the slag line subject to attack from the metal. For the present purpose it should suffice to deal only with item (2), and it is assumed that the material of which the furnace banks are constructed will consist entirely of burnt dolomite.

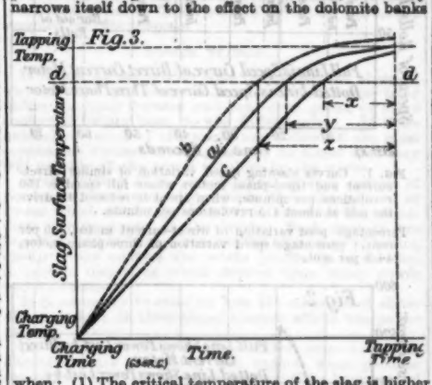
In Table VI is given a typical analysis of dolomite taken from the banks of a furnace at the slag line, and for comparison the analysis of the original dolomite before use.

Table VI.

	SiO_2.	CaO.	P_2O_5.	MnO.	MgO.
Original dolomite..	3·0	57·0	...	...	32·0
After use	13·20	40·70	2·51	3·16	23·68
		Al_2O_3	FeO.	Fe_2O_3	S.
Original dolomite		3·25	...	...	...
After use		1·10	2·83	11.22	0·29

It will be seen that the dolomite deteriorates greatly in use, and can be considered only as a solid slag with a high critical viscosity temperature.

Having fixed the lowest critical temperature compositions of slags found in steel furnaces, the study narrows itself down to the effect on the dolomite banks



when: (1) The critical temperature of the slag is higher than the lowest melting point slag, through greater acidity; and (2) The critical temperature is higher, through greater basicity.

Condition 1.—As has already been mentioned under the heading of "Silicate Slags," any silica oxidised from the metal and present in the slag, over and above the amount required to give the lowest critical viscosity composition, will combine with any available bases to become passive, and if basic additions are not available the silica will react with the dolomite banks. This reaction is not a rapid one at the temperatures at which such conditions exist in steel furnaces, and the "time lag" makes the reaction comparatively unimportant. As an example of this "time lag" is given the following analysis of basic Bessemer slag, made under the Massenez patent at the works of Messrs. Bolckow, Vaughan and Co., Limited:—*

SiO_2.	CaO.	P_2O_5.	MnO.	MgO.	Al_2O_3.	FeO.
53·77	27·47	0·67	4·27	2·80	7·02	4·11

Undoubtedly the speed of working in the Bessemer process is very great, but chemical action on the lining of the vessel, as denoted by the magnesia content of the slag, seems to have been practically nil.

Excess acidity by phosphoric acid is of no importance, as the phosphorus returns to the metal if no bases are available to keep it in combination with the slag.

The extra fluxing power obtained from the excess bases in a highly ferruginous slag will have no direct chemical action on the dolomite, and the bases will, while carbon is present in the metal, readjust themselves by the balancing reactions already referred to. They may have some influence on the deterioration on the dolomite itself by combining with the lime contained in it. The effect of a "seething" and "foaming" slag will also have an erosive effect on the lining.

Condition 2.—Should the slag be more basic than the lowest critical viscosity temperature composition, the temperature and viscosity of the slags are the factors to be considered.

When the slag is too fluid the influence of the balancing reactions is to attack the dolomite lining, so as to give a slag composition that will be less fusible.

The influence of temperature is of great importance in its effect on the impure dolomite lining. The higher the temperature, the nearer will the impure dolomite be brought to its softening point, and the more easily will it be attacked by a fluid slag.

A furnaceman, and particularly one used to tilting furnaces, will often notice that, during the earlier period of the charge, and when the slag is more highly acid and the temperature low, the furnace banks are only slightly attacked; and yet towards the end of the charge, when the slag is more basic and the temperature high, the furnace banks are heavily attacked.

The ideal furnace slag from the furnace bank point of view will be one that will give ideal viscosity throughout the working of a charge, and at the same time be at the lowest temperature. The ideal degree of viscosity cannot be expected throughout the whole period of the charge, but the conditions giving high temperatures and high slag surface superheat are worthy of every consideration.

Conclusion.

The author's efforts in the foregoing are directed towards that wider knowledge which is so much to be desired of the laws governing steel furnace practice: a clearer knowledge of these laws or principles is the only sound basis for future advance. The foregoing notes are derived essentially from the author's practical experience, and it is hoped that they may be found useful in actual furnace operation.

* A. W. Richards, Journal of the Iron and Steel Institute, 1907, No. I p. 113.

PHYSICAL SOCIETY OF LONDON.

At the meeting held on April 23, 1920, at the Imperial College of Science, Sir W. H. Bragg, F.R.S., President, in the chair, the fourth Guthrie lecture was delivered by M. Charles Edouard Guillaume, his subject being "*The Anomaly of the Nickel Iron Alloys; Its Causes and Its Applications.*"

The lecturer began by a reference to the work of John Hopkinson, and to his own early work on the perfecting of standards of length. His first experiments were on nickel, which had two great advantages over brass for metrological work, viz.: its smaller coefficient of expansion and greater freedom from corrosion. He would probably not have looked further but for the difficulty at the time of getting large bars of the material free from flaws. In investigating the ferro-nickel alloys, his first experiments were on their magnetic properties, as these were easier to investigate than the coefficients of expansion. He showed and explained curves showing the variation of magnetic properties, and of the coefficients α and β in the expansion equation $l = l_0(1 + \alpha\theta + \beta\theta^2)$ for alloys both in the irreversible and reversible categories, and showed from the curves how it was possible to obtain alloys with any desired coefficient. The anomalous magnetic behaviour of some of the alloys was illustrated by demonstration experiments of the effect produced on the magnetic condition of bars of the materials by dipping in hot water of liquid air. He then dealt with the properties of ternary alloys containing iron, nickel and a third element. Manganese alloys were those most extensively used. He exhibited a cardboard model of Guthrie's three-dimensional diagram for ternary alloys. The addition of the third element raised the minimum expansion. In the case of carbon and chromium the elastic constant is raised. The curve connecting Young's modulus with the percentage of nickel in ferro-nickel alloys also showed an anomaly in the same region as the expansion.

The chief weakness of the alloys from the point of view of the metrologist was instability. If a piece of invar was cooled from a high temperature in air at 100 deg. C. its length reached a steady value in about 100 hours. If it was then cooled to 50 deg. C. its length would increase to another steady value, reached in about 1,000 hours or so. If it were then cooled to zero it would still further lengthen, a steady state not being reached for a very long time. If the temperature were then raised again to 100 deg., the length would diminish to its initial value for 100 deg. The total change of this character between 0 deg. and 100 deg. amounted to about 30 millionths of the length.

With increasing carbon content the instability very rapidly increased. It was possible from the amount of the instability to estimate the carbon to 1/100th per cent. Moreover, the curve connecting the instability and the carbon content passed through zero, showing that the instability was due to the carbon. It was, therefore, possible to get an invar of perfect stability.

Among the applications to which invar had been put, the speaker instanced pendulum rods, leading in wires for electric lamps (an alloy being chosen from the curves so as to have the required coefficient of expansion), wire standards for base measurements in surveying, &c., and showed curves of the variation of height of the Eiffel Tower with temperature, as measured relatively to invar wires.

Another important application of those alloys was in chronometer construction. The temperature coefficient of the rate of a watch was due to variation of the elasticity of the hair-spring. This was corrected in the Graham compensation by a variation of angular momentum of the balance wheel, depending on the difference in expansion of two metals; but it was possible to choose for the spring a nickel steel having a temperature coefficient of elasticity nearly zero. If chosen to give the same rate at 0 deg. and 30 deg., there would be a secondary error of only 20 seconds per day at 15 deg. But a more important chronometric application was the correction of the secondary error of two seconds in Graham's compensation. This error, discovered by Dent in 1832, is due to the fact that the variation of elasticity of the hair-spring is not a linear function of the temperature, whereas the variation of angular momentum of the balance wheel is. If, however, for one component of the bimetallic compensator a nickel steel of negative β be chosen, it is possible to get a curve connecting the momentum with temperature which exactly compensates the elasticity variation over the whole range.

Reverting to the curves for Young's modulus, the

lecturer predicted that an alloy would shortly be produced having a practically constant modulus over a range of 200 deg. C.

Sir R. T. Glazebrook, in proposing a vote of thanks to the lecturer, said that everyone in the room must have realised for many years the value and importance of invar, and would be glad to have met its discoverer; but they should not forget his other claims as a scientist. It was largely to the work of M. Guillaume in the early days of the Bureau at Sèvres that they owed their knowledge of mercurial thermometry. Returning to the subject of the lecture, he didn't know whether he most admired the skill which the work that had been described to them involved, or the courage of the lecturer who had spoken for two hours in a foreign language without notes. The lecturer had illustrated the important connection between science and industry, and how, if that connection were to be strong and productive of the best results, it was necessary that scientific investigations should be carried out to their fullest extent. They had seen how, in the first place, the various physical properties of these steels had been examined, and how the results so obtained had subsequently been of the highest value in solving problems of great practical importance. The curve connecting the height of the Eiffel Tower with temperature had reminded him strongly of a similar curve for the variations in length of the wall on which the 50 metre standard at the National Physical Laboratory was mounted. That curve was also based on invar tapes. There were several of these tapes at the laboratory, and some discrepancies of the order of two parts in a million between the laboratory measurements and those made at Sèvres were causing some little concern to the Metrology Department.

Professor Sir A. Schuster briefly seconded the vote of thanks, which was carried enthusiastically.

ELECTRIC DRIVE OF STEEL WORKS PLANT.

*Direct Current Compared with Three-Phase Current for Driving Steel Works Plant.**

By C. A. ADLETT, M.Inst.C.E., London.

MANY steel works and rolling mills have adopted three-phase alternating current electrical plant, whilst many have adopted direct-current electrical plant, so there is obviously a difference of opinion regarding the relative merits of three-phase and direct current. There is justification, therefore, for a general consideration of the advantages and disadvantages of the two systems.

The principal advantage of a three-phase system is that it enables power to be transmitted cheaply over long distances at high voltages, and this system is therefore almost universally adopted by power supply authorities. It has, however, the disadvantage that three-phase motors are not capable of speed variation without considerable loss of power, unless they are of a complicated and costly type, and therefore not well suited to many steel works purposes.

Direct current, on the other hand, does not lend itself to cheap transmission of power over long distances, but as in most iron and steel works distances are relatively small, this point is not usually one of any great importance. Direct-current motors are naturally capable of speed variation over a wide range without loss of power, and this and other natural characteristics of direct-current motors render them very suitable for many steel works purposes.

The method of applying electrical power to the various plant in steel works may be considered in detail as follows:—

ROLLING MILLS.

(*a*) *Merchant and Bar Mills.*—Most of the merchant mills and bar mills in the British Isles roll a large number of different sections, of which the heavier should be rolled at low speeds and the lighter at high speeds. To get the best results and output from the mills, each section should be rolled at its own particular speed. If such a mill be driven by a direct-current motor, the speed can easily be regulated through a very wide range by a shunt regulator in the motor field without entailing any loss of power, and, as the speed of the motor is reduced, the turning moment increases, so that the maximum turning moment is available where it is required for rolling the heavy sections at slow speeds.

The direct-current motor possesses a further advantage—its speed remains at about the basis speed corresponding with the setting of the shunt regulator, so that the mill does not run up to high speeds when the bar is out of the rolls.

As an example may be quoted a 400-h.p. motor which was installed to drive an 11-in. merchant mill which could be so regulated that the mill would run at any speed between 60 r.p.m. and 250 r.p.m. Supposing this motor were set to drive a mill at a speed of 60 r.p.m., it would not, if there were no bar in the rolls, run at a higher speed than 66 r.p.m. Closer speed regulation than this could be obtained, which would mean a better tonnage from the mill, but a greater variation of the power of the motor. If an ordinary three-phase motor were employed, the speed could only be reduced below the full speed by inserting resistances in the rotor circuit, which resistances would cause waste of power nearly proportional to the reduction in speed of the motor.

The three-phase motor cannot give any increased turning moment at the low speeds, but on the contrary tends to lose its overload capacity as the speed is reduced, so that to obtain large turning moments at reduced speed, a large and more expensive motor must be installed. When driving a mill at reduced speed, the three-phase motor tends to run up to full speed as soon as the bar leaves the rolls, and also tends to fall greatly in speed while rolling a heavy section, so that the speed varies greatly, which means a poor tonnage from the mill.

Figs. 1 and 2, which give a comparison between the working of a 1,200 h.p. direct-current motor and a 1,200 h.p. three-phase motor driving a mill, illustrate these points.

The full speed of the direct-current motor and the synchronous speed of the three-phase motor are 150 r.p.m. and the speed of each motor is reduced so as to drive the mill at 115 r.p.m. A few passes only are shown in the figures for the sake of simplicity.

Fig. 2 shows that the power lost in the three-phase motor is nearly three times as great as in the direct-current motor, and it should be pointed out that while, if the mill were driven by a three-phase motor, a 1,200-h.p. motor would be required, on the other hand, if it were driven by a direct current motor, a smaller motor than this could be employed with a corresponding reduction in the amount of power lost.

Fig. 1 shows that the speed of the three-phase motor cannot be properly controlled, as it varies from 95·2 r.p.m. to 147 r.p.m.—a variation of 44·8 per cent.—the speed

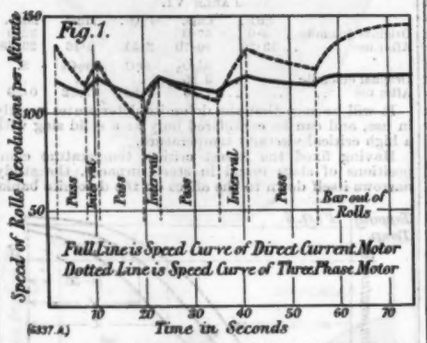


FIG. 1. Curves showing speed variation of similar direct-current and three-phase motors whose full speed is 150 revolutions per minute, when speed is reduced to drive the mill at about 115 revolutions per minute.

Percentage speed variation of direct-current motor, 8.5 per cent.; percentage speed variation of three-phase motor, 44·8 per cent.

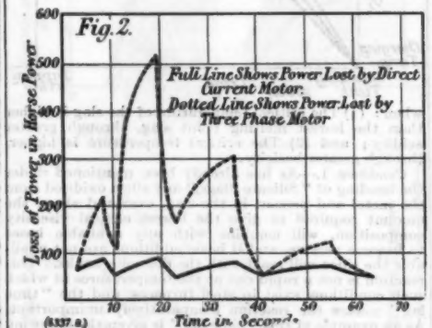


FIG. 2. Curves showing a comparison of the loss of power in the direct-current and three-phase motors under the same conditions as Fig. 1.

Loss of power in three-phase motor is 2·92 times that of direct-current motor.

rising to 147 r.p.m. when the bar leaves the rolls. The variation in speed of the direct-current motor is 8·5 per cent., this variation being allowed to enable the flywheel to assist the motor, and this speed variation is capable of being reduced. It will readily be understood from Fig. 1 how greatly the output from the mill would be reduced if it were driven by a three-phase motor, owing to the impossibility of keeping the speed under control.

A number of devices have been used to overcome these inherent difficulties of the three-phase motor, and while they enable speed regulations to be obtained without excessive loss of power, and some of them enable the speed to be kept reasonably under control, they usually entail the use of more than one machine, are always much more expensive in capital expenditure, are less economical, and more complicated than the plain direct-current motor.

The operation of a rolling-mill motor and flywheel must next be considered, as the majority of rolling-mills are provided with a flywheel. To enable the flywheel to take part a part of the power required during a pass, the motor must automatically fall in speed during the pass. This variation in speed under practical conditions—that is, with a flywheel of moderate size and without undue variation in the power taken by the motor—can easily be 10 per cent. to 15 per cent. of the motor speed.

If a direct-current motor be used to drive the mill, this automatic variation in speed can easily be arranged by providing a compound winding in the motor field, which does not entail loss of power. On the other hand, if a three-phase motor be used, the variation in speed is obtained by inserting resistances in the rotor circuit, so that, when the speed falls by 15 per cent., practically 15 per cent. of the motor power is wasted. If the speed variation is to be less than this—which is, of course, an advantage from the point of view of obtaining a greater output from the mill—either a greater variation in the motor power must be allowed or a heavier flywheel must be used; and there is not much scope in the latter direction, as the practical limit in flywheel weight is soon reached.

The author does not refer to devices which have been employed for varying the speed of mill motors intermittently, such as the so-called automatic slip regulator, because in his opinion they are too slow in action to be of value with the type of mill which is here referred to.

The foregoing remarks show that three-phase current is unsuitable for driving merchant and bar mills. Compared with direct current it is either wasteful of power, involves loss of output from the mill, or involves an unduly high capital cost. Three-phase current has, however, been extensively used in America for driving mills, but there commercial conditions are different from those prevailing in the British Isles, for the tendency in America is for large tonnages of a particular section to be rolled in one mill, so that the question of speed regulation becomes of less importance than in Great Britain, and consequently the three-phase motor is not at so great a disadvantage. In visiting American mills the author has nevertheless seen a number of cases where three-phase current has been used where better results would be obtainable with direct current.

It may be pointed out that where means are available for readily varying the speed of the mill, increased output is sometimes to be obtained by gradually increasing the speed of the mill as each billet is being rolled, so that the first passes on the billet are made at a moderate speed, and the last passes on the finished section are made at a high speed. This method of working has been developed to a considerable extent in certain large three-high Continental mills where very large tonnages are obtained. While the majority of mills of this description have been driven, with good results, by a motor coupled to a flywheel, there is, in the author's opinion, too great a tendency to accept the flywheel without considering the possibility of obtaining an increased output if it were dispensed with. When a new mill is being put down, this point should receive full consideration. A rolling-mill motor should not be regarded merely as a motor to drive a rolling mill but, if the best results are to be obtained by electric driving, the rolling-mill plant, if new, and the mill motor should be suited to one another, and both the mill and motor be considered as a combined plant.

It should be remembered that rolling-mill plants have been developed in connection with the steam drives. The electric motor has certain different characteristics from the steam engine, and the full advantage should be taken of these differences.

(*b*) *Sheet and Tin-Plate Mills.*—The proportion of sheet and tin-plate mills which are driven electrically is not so great as the proportion of merchant and bar mills, and the statement has frequently been made that it is cheaper to drive hot mills by steam than electrically. The author believes that there is a foundation for this statement, and that the reason is as follows:

The speed of the rolls in such mills is usually from 30 r.p.m. to 40 r.p.m., depending on the roll diameter, and when driven by a steam engine, the engine is generally direct coupled. Where electrical driving has been adopted, a motor running at a comparatively high speed has been used which drives the mill by ropes or by gearing. Now, the variations in the power required to drive such mills are very great indeed, perhaps greater than with any other type of mill, so that the average power consumption is only a small fraction of the maximum power.

The rope or gear drive entails a certain loss of power which is going on continuously, so that, while this loss of power may be only a small percentage of the maximum power, it still forms a very substantial addition to the average power, so that it materially increases the power consumption measured in kilowatt-hours per ton rolled.

If a three-phase motor be installed to drive such a mill, this loss of power would be accentuated by the loss which occurred in the resistances connected in the rotor circuit, which are necessary to enable the flywheel to give up power when required, and these losses, while they may be only a small percentage of the maximum power, make a substantial addition to the average power taken, thus materially increasing the power consumption expressed in kilowatt-hours per ton rolled. Now, in the author's opinion, if such a mill be driven by a slow-speed motor running at 30 r.p.m. to 40 r.p.m., as the case might be, the running costs of the electrical drive would be found to be considerably cheaper than those of the steam engine, for these various losses of power would be eliminated. From results in the author's possession, he considers that the adoption of the direct drive would be found to reduce the power consumption expressed in kilowatt-hours per ton by something like 40 per cent.

There is no engineering difficulty in installing a direct current motor running at a speed of 30 r.p.m. for driving a sheet mill. Such a motor would be larger and more costly than a high-speed motor, but when all the circumstances are taken into account the savings to be effected should be found to make a very substantial return on the extra capital cost. On the other hand, there are some very serious engineering difficulties to be met with in constructing a three-phase motor to run at a speed of, say, 30 r.p.m. If the electrical supply were 50 cycles, the motor would have to have 200 poles, which shows how large and unwieldy it would be, and in addition the power factor would be so low that the operation of the power generating plant and supply system would be very adversely affected.

The above remarks apply only to the hot mills in sheet and tin-plate works, and not to the cold rolls, which

* Paper read before the Iron and Steel Institute, May 6, 1920.

require practically constant power to drive them at a constant speed, so that for cold-roll driving there is very little to choose between direct current and alternating current.

(c) *Other Rolling Mills.*—The author has, for the sake of brevity, omitted a comparison between alternating and direct current for driving continuous mills, wire mills, tyre rolling mills, tube rolling mills, and other specialised mills. He is of opinion that substantial increases in output and other advantages could be obtained by driving many mills of this type by direct current motors rather than by alternating-current motors, and that a very great deal remains to be done in this direction.

(d) *Reversing Rolling Mills.*—The electrical driving of reversing rolling mills has now found such wide adoption, and has been so frequently described, that for the purposes of this paper it is only necessary to recall that the reversing mill itself is driven by a direct-current motor, and that this motor is supplied with current from a motor generator set coupled to a heavy flywheel.

The motor of the motor generator set would have a normal power of about one-fifth or one-sixth of the power given by the mill motor when at work, and in the present instance we are concerned with the question whether it is better that this motor generator set should be driven by an alternating current motor on a direct-current motor. For example, a 2,000-h.p. motor may be used to drive the motor generator set, of which the flywheel at full speed would have a total stored energy of 200,000 h.p. seconds, of which 72,000 h.p. seconds would become available for neutralising the variations in the power.

The speed of this 2,000-h.p. motor would be so varied by some form of relay connected in the power circuit supplying the motor that the power in this circuit would be maintained at as near a steady value as possible—that is to say, that the speed of the motor would be reduced when the bar is in the rolls, so that the flywheel could supply part of the power required by the mill motor, and when the bar is out of the rolls the speed of the 2,000-h.p. motor would be increased, thus increasing the stored energy of the flywheel. In some works this relay has been connected in the main power circuits of the power-house, so that the flywheel of the reversing rolling-mill equipment is not used merely to maintain the power required to drive the reversing mill at a constant value, but for a much more useful purpose—namely, to keep the power supplied by the power-house as constant as possible by providing the power required for heavy peaks of short duration, which may be caused by other parts of the plant, from the stored energy of the flywheel. This is a valuable asset, because if the power is supplied from a gas-engine power station, of which the overload capacity is not very great, it may save an additional engine, and in any case the more constant the power-house load is kept, the cheaper the supply of electrical power becomes.

If the 2,000-h.p. motor driving the motor generator set is a direct-current motor, it would not only cease to take power from the power station if a heavy peak occurs elsewhere in the works, but could act as a generator and could supply electrical power drawn from the stored energy of the flywheel to help the power station. For a peak of short duration the motor thus acting as a generator can work up to double its normal capacity, and can help the power station to the extent of something approaching 6,000 h.p. for a short time. If, however, a three-phase induction motor were used to drive the motor generator set, it cannot generate power to help the power station, but can only cease to take a considerable portion of its power from the power station. This can be summed up by saying that the direct-current can actively assist the power-house while the three-phase motor can only do so passively, and that the direct-current motor is about three times as effective as the three-phase motor in helping the power-house to overcome peaks.

It has also been pointed out that the motor generator set has to be made to fall in speed artificially so that the flywheel can give the surplus power required by the reversing mill motor; this fall in speed would be of the order of 20 per cent. If a direct-current motor be used to drive the motor generator set, this fall in speed does not entail any loss of power, but if a three-phase induction motor be used, the 20 per cent. fall in speed means that a considerable proportion of the power supplied to the motor is wasted.

On the average it may be taken that 10 per cent. of the power supplied to the three-phase motor is wasted, which would increase the kilowatt-hours per ton, and consequently the cost of power for rolling by 10 per cent.

A motor generating set driven by a three-phase alternating motor is limited to certain speeds corresponding to the synchronous speed of this motor. If the supply be 50 cycle, the synchronous speeds within the practicable range would be 600 r.p.m., 500 r.p.m., 428 r.p.m. and 375 r.p.m. It may happen that the flywheel or the variable voltage generators could run at higher speeds than the corresponding synchronous speed, so that if they are driven by three-phase alternating current motors they are not being used to the best advantage, and if a direct-current motor were used the motor generator set could be run at a higher speed, and thus the capital cost of the reversing rolling-mill plant could be reduced.

(e) *Live Roller Gear.*—The electrical drive of the live roller gear require careful consideration, for if live rolls cannot be handled rapidly a good output cannot be obtained from the mill, however good it may be.

The following considerations will show that live roller gear driven by direct-current motors can be handled more rapidly than if they were driven by three-phase alternating current motors.

The turning moment of the direct-current series motor varies with the square of the current, while that of the alternating-current motor varies directly as the current—that is to say, if each type of motor is giving the same turning moment for a definite current, and then the currents be increased to double, the direct-current motor has the advantage of giving twice the turning moment which can be obtained from the alternating-current motor. It is easily seen, therefore, that the direct-current motor can accelerate the live rolls much more rapidly than the alternating-current motor.

Conversely, in decelerating the live roller gear, the direct current motor gives a much more powerful retarding effect than the three-phase motor, so that the direct current series motor proves a more effective machine for reversing live roller gear than the three-phase motor.

It may be argued that larger three-phase motors may be used to give sufficient turning moment for rapid acceleration, but if this be done it must be remembered that not only is the capital cost increased but that the stored energy of the motor armature, which runs at a high speed, begins to form an appreciable proportion of the total energy of the live rolls, so that, in providing a larger motor to do the work, more work is also provided for it to do. Another disadvantage of the three-phase alternating-current motor is that its turning moment is proportional to the square of the voltage, so that if the voltage falls, say, 10 per cent. the turning moment is decreased by 19 per cent. The turning moment of the direct-current motor is directly proportional to the voltage, so that in a similar case the turning moment of the direct-current motor would only be decreased by 10 per cent. This tends to make the three-phase alternating current motor sluggish where voltage variations occur.

In a certain large American steel works where there is a large power-house in the works generating three-phase current, direct current live roll motors have been installed throughout for this very reason, and the whole of the power for driving these live-roll motors is converted from three-phase to direct current by rotary converters supplied for this purpose.

Power Station.

It is now agreed within wide limits that the cheapest way of obtaining power in iron and steel works is to utilise the blast furnace and coke-oven gases, or other sources of waste heat, to the fullest extent. If these natural resources of the works are utilised in the most economical manner it will generally be found that they will provide all the power required by the works.

In the history of the development of such sources of power there are generally periods when the amount of power which can be produced is in excess of the immediate requirements of the works. Such periods are bound to be transitory, because the advantage of having cheap power enables the works profitably to develop in certain directions which depend upon cheap power for their success.

It is necessary to consider how the adoption of either direct current or three-phase current affects the power plant.

(a) *Gas-Engine Power Station.*—Where large slow-speed alternators are driven by gas engines some peculiar resonance effects can be produced, and these have proved exceedingly troublesome in certain power-houses. These resonance effects may be briefly explained as follows:

Assume that a large flywheel alternator be excited and disconnected from its engine—the flywheel has a certain moment of inertia and is acted upon by magnetic forces between the fields and the armature. If the flywheel be slightly displaced by external forces in the direction of its rotation, it will commence to swing backwards and forwards, each swing taking a definite time, which is called the natural time of vibration. This alternator is quite analogous to the simple pendulum in which the bob has a certain moment of inertia and is acted upon by the force of gravity, and if displaced by an external force will swing to and fro' to a natural time of vibration.

The natural time of vibration of a pendulum can be varied by altering its moment of inertia by altering the length of the pendulum. Similarly, the natural time of vibration of an alternator can be varied by altering the moment of inertia of the flywheel, and it can also be varied in another way by altering the strength of the magnetic field.

If the alternator be driven at a uniform speed by its engine, it can be set swinging, say, by a sudden overload or other causes, and it will then be swinging at its natural time of vibration about its uniform speed of rotation—that is to say, it will be moving faster at one moment than the average speed, and slower at another moment. If the alternator and flywheel are properly designed, these vibrations, when once started, will die away quickly. If, however, the natural time of vibration happens to coincide with the time which elapses between the successive working strokes of the engine or certain multiples of them, the vibration may become so violent that it is impossible to run the engine. This is a case of forced vibrations, and is again analogous to that of the pendulum, where, if the bob be tapped each time at the end of its swing, its vibrations will become very large.

If a number of gas-engine driven alternators be running in parallel, serious difficulties can occur by the natural time of vibration of one of the alternators coinciding with the time between the working strokes of an engine driving another machine, so that it becomes impossible to run the two machines in parallel. The author has had experience of several cases of this kind where difficulties occurred which could easily have been avoided.

To avoid the possibility of such resonance between the natural time of vibration of the alternator and the time between the working strokes of the engine, the proper weight of the flywheel has to be selected. This weight is generally greater than would be necessary to secure uniform running of the engine if it were not driving electric machinery, but the weight may be made too great, and too heavy a flywheel may be just as harmful as a flywheel which is too light. If the gas engines drive direct-current dynamos these resonance effects do not occur, and consequently a much lighter flywheel is required than if alternators were being driven.

Gas-engine driven direct-current machines are usually cheaper in capital cost than gas-engine driven alternators, and have the advantage from the engineering standpoint that these resonance troubles do not take place.

(b) *Steam Turbine Power Station.*—Steam turbines direct coupled to three-phase alternators have been built in such large sizes and have proved themselves to be so reliable that they call for no special comment here.

In the past a number of high-speed direct-current turbo-generator sets with dynamos direct-coupled to steam turbines running at speeds up to about 2,000 r.p.m. have been installed in steel works with satisfactory results, and those of which the author has knowledge have proved themselves very reliable. The modern tendency, however, is to build direct-current turbo-generators with a high-speed turbine driving a comparatively slow-speed dynamo through some form of double helical gearing or a development of it. Up to the present such machines have been built in sizes up to 6,000 kw., and it is probable that natural development will lead to the construction of considerably larger sizes and that the turbines will run at higher speeds than 3,000 r.p.m., which is the highest possible speed of a three-phase 50-cycle turbo-alternator. Such gear-driven sets have proved themselves to be very reliable in operation, and from the engineering standpoint there is little to choose between three-phase and direct-current turbo-generators.

The capital cost of the direct-current geared turbo-generator is higher than that of a three-phase turbo-generator, so that a power-house containing direct-current turbo-generators would prove more costly than one containing three-phase current turbo-generators. The question to be decided, therefore, is what return the more economical application of direct current in the steel works will make on the increased cost of the power-house.

Power Supply Authorities.

It has been shown that under many conditions it is advantageous that direct current should be adopted as the system of supply of a steel works, and this naturally leads to the consideration of the question of linking up with the power supply authority, because practically all power supply authorities, such as might be considered in such a case, supply three-phase alternating current.

The first question to be considered is the reason why it should be suggested that an iron and steel works should be linked up with a power supply authority at all, and the following reasons have been advanced in favour of linking up:—

(a) That the power supply authority provides a standby to the works power-house.

(b) That the power supply authority provides a possible market for the surplus power of the works.

Neither of these reasons, if examined from the power company's point of view, will be found to contain as much substance as might appear at first sight.

Dealing first with the question of a standby, it is evident that if a power supply authority undertakes to provide a standby of, say, 1,000 kw., it must invest capital in an additional 1,000 kw. of plant in its boiler-house and power station, and also invest a considerable capital sum upon its distribution system over and above the plant needed for its normal requirements.

The power supply authority naturally has capital, depreciation, and maintenance charges to meet on this additional plant provided for standby purposes, and to make certain that it should not be out of pocket to the extent of these charges, it must provide for a definite payment per kilowatt which it contracts to keep as a standby and to supply upon demand, whether it is demanded or not.

For the purpose of illustration, assume the capital cost to the supply authority of the plant and distributing system for providing 1,000 kw. standby to be 40,000*l.* Then the power supply authority would make a minimum annual charge of the order of 6,000*l.* to recompense it for out-of-pocket expenses—namely, capital, depreciation, maintenance charges, &c.—on the standby plant, whether this plant is used to supply power or not, and in addition if power is required from this plant it would make the ordinary charge per unit of electricity supplied.

The standby supply may be regarded as an insurance against exceptional circumstances. If an insurance were to be effected with an ordinary insurance company, the works owner would have the choice of many companies with whom he could contract, and would take very good care before entering into any bargain to assure himself of the capacity of the insurance company to carry out its obligation. Where what is really an insurance is effected with a power supply authority, which is in effect a monopoly, it is even more necessary for the works owner to assure himself that the power supply authority is carrying out its obligation by providing at the commencement and during the whole term of the agreement the plant necessary for providing a standby supply at any time at which it may be required. It is quite easy for the works owner to test the power supply authority by demanding the standby supply occasionally unexpectedly, and to see whether it can be given or not.

It would appear better for a works having blast-furnace gas, coke-oven gas, or other natural sources of power, to instal their own standby plant rather than pay other people to do it for them. If they install their own plant and charge themselves annually a similar sum to that which they would be paying a power supply authority, the cost of the plant would soon be paid off. If, on the other hand, they rely upon the power supply authority, this annual charge goes on perpetually.

In considering the second point—namely, that the power supply authority provides a possible market for

surplus waste heat power for the works—the question arises of what price the power supply authority would be willing to pay for this surplus power.

A power supply authority is usually willing to pay 0·05*d.* (one-twentieth of a penny) per unit of surplus electrical power delivered to it by a works, and as on the other hand the power supply authority usually charge about 0·5*d.* (one-halfpenny) to 1·0*d.* (one penny) per unit, including all maximum demand, coal charges, &c., which go to make up the total price, in selling its power to a works, the power supply authority is apparently making a very substantial profit on any surplus power which it buys. If this be considered from the power supply authority's point of view, it will be seen that surplus power is not of great value to the power supply authority because, as a rule, it cannot be supplied to it when it is of value.

In order that the power supply authority should work in a most economical manner, it is necessary that they should work their plant as continuously as possible at its full output. They have, however, to supply a much larger power during the ordinary working hours of the week than at other times, which means that at these other times they have a good deal of plant standing idle and not earning any money. If the power supply authority could depend on regularly obtaining a considerable supply of surplus power during the ordinary working hours of the day, this would be of great value to them, and they would probably be prepared to pay a good price for it, because it would mean that they would be able to conduct their business with less plant and to keep their plant more continuously employed. The works, however, as a rule need the full output of their own power plant for themselves during the ordinary working hours of the day, and could only supply surplus power to the power supply authority at other times when the power supply authority does not need it, and when it is, in consequence, of little value to them.

While the power supply authority as a rule are only required to supply very little power at the week-ends, it would not be economical for them to shut their plant down and to purchase surplus power to provide their week-end supply.

It is evident therefore from the above remarks that the interests of the iron and steel works having their own power resources and those of a power supply authority do not coincide, and as a power supply authority are bound to make such considerable charges for standby plant, and as they can only pay so small a price for surplus power, which is less than the cost of production, there appears to be no advantage in linking up with the power supply authority, and that it would be more profitable to the iron and steel works to find a means for using their own surplus power, which is one of their valuable assets.

Many such means can be suggested, but this is considered to be beyond the scope of this paper.

THE REDUCTION OF SILICON FROM THE SLAG IN THE ACID OPEN-HEARTH PROCESS.*

By B. YANESKE and G. A. WOOD, Sheffield.

IT frequently occurs that the percentage of silicon found in finished steel made by the acid open-hearth process is much higher than is required in the specification, although only the same weights of finishing materials have been added which normally yield the desired amount of silicon. In such cases the silicon present in the steel may be much more than is known to have been added by the finishing materials after allowing for the usual residual silicon in the metal previous to their addition. This points conclusively to the fact that there must have been more than the usual amount of residual silicon in the metal, and therefore that either this element has never been satisfactorily eliminated during the working of the charge, or that after being eliminated it has passed back into the metal as the result of reduction from the slag.

It is well known by metallurgists that the reduction of silicon, under certain conditions, does take place in the acid process, but very little investigation appears to have been made regarding the statements of some authorities relating to the nature of this reaction. The occurrence of the reaction is due to the bath having been allowed to remain for too long a period without ore or lime additions, whilst a very high temperature has been maintained, thereby causing the formation of a highly siliceous slag. In this way the slag becomes so siliceous that it contains more silica than is required to combine with the basic oxides in the slag to preserve an equilibrium. This excess silica is therefore decomposed and the silicon passes into the metal. Just in the same manner as it is the excess of FeO above that required to satisfy the SiO_2 of the slag which does the work of oxidation of the carbon and silicon, so any excess of SiO_2 in the slag is liable to be reduced.

H. H. Campbell, in his excellent treatise on "The Manufacture and Properties of Structural Steel,"† states that by holding the bath at a very high temperature with a siliceous slag, there will be a reduction of the silica of the hearth according to the equation:

$$SiO_2 + 2C = Si + 2CO.$$

That carbon effects the reduction of silicon appears to have been taken for granted by many metallurgists, and the preceding equation has frequently been quoted by them, but the authors of the present paper have never seen any evidence that such a reaction occurs in practice, and they began to doubt that carbon was the reducing agent when it was repeatedly found that whenever the percentage of silicon in the finished steel was abnormally high there had been less loss of carbon than usual from the finishing additions, with the result that the percentage of this element was also found to be high.

In a paper read before the Iron and Steel Institute in 1902 by McWilliam and Hatfield,* the authors gave the results of two experimental charges, during the working of which the composition of the slag in relation to silica and oxide of iron was varied to observe the effect on the removal of impurities. The results showed that both silicon and manganese can be reduced from the slag and passed back into the metal, this being attributed by the authors to the composition of the slag and not to its fluidity nor to the temperature of the hearth, with which conclusion the present authors agree, but the tables given in the paper referred to do not prove in any way that the reduction of the silicon is effected by the carbon as put forward as an explanation by Dr. Stead in his discussion of the paper,*, when he stated that iron containing carbon perfectly free from silicon and manganese, when at an intensely white heat in the presence of free silica or very siliceous slags, reduced the silicon according to the equation:

$$SiO_2 + 2C = Si + 2CO.$$

Now the essential conditions for bringing about a substantial reduction of silicon from the slag cannot always be obtained at will, and any attempt to compare the loss of carbon from the metal with the corresponding gain in silicon by working experimental charges, would most probably fail in its object owing to the influence of atmospheric oxidation effected by the action of the furnace gases, which is very considerable during the "boil." It is obvious that before silicon can be passed into the metal from the slag, the amount of dissolved oxygen in the metal must have reached a minimum.

TABLE I.—DETAILS OF CHARGE NO. 1.

Finishing.	Composition of Finishing Materials.			Time.	Weight added. Percentage of Total Charge.	Composition of Bath and Added by Finishing Materials.			Composition of Slag.		
Materials.	C.	Mn.	Si.	Hr. Min.		C.	Mn.	Si.	SiO_2.	FeO.	CaO.
Bath	—	—	—	9 25	—	0·585	trace	0·048	—	—	—
Bath	—	—	—	9 48	—	0·53	trace	0·053	57·7	19·7	5·3
Ferro-silicon	1·98	1·76	10·58	9 50	1·50	0·03	0·026	0·159	—	—	—
Ferro-manganese	6·49	77·85	0·63	10 20 (Ladle)	1·05	0·068	0·817	0·007	—	—	—
Ferro-silicon	0·22	1·01	23·50	Ladle	0·50	0·001	0·005	0·117	—	—	—
			Furnace tapped	10 41	Total	0·629	0·848	0·336			
					Composition of finished steel	0·60	0·88	0·451			
					Loss of carbon	0·029	—	—			
					Gain of silicon	—	—	0·115			

TABLE II.—DETAILS OF CHARGE NO. 2.

Finishing.	Composition of Finishing Materials.			Time.	Weight added. Percentage of Total Charge.	Composition of Bath and Added by Finishing Materials.			Composition of Slag.		
Materials.	C.	Mn.	Si.	Hr. Min.		C.	Mn.	Si.	SiO_2.	FeO.	CaO.
Bath	—	—	—	10 47	—	0·605	0·03	0·066	—	—	—
Bath	—	—	—	11 3	—	0·58	0·05	0·121	60·6	17·3	4·7
Carnforth pig-iron	3·85	0·60	2·07	11 5	2·00	0·077	0·012	0·041	—	—	—
Ferro-silicon	1·06	1·68	11·13	11 27	1·25	0·025	0·021	0·139	—	—	—
Ferro-manganese	6·59	78·15	0·34	Ladle	1·00	0·066	0·781	0·003	—	—	—
			Furnace tapped	11 43	Total	0·748	0·864	0·304			
					Composition of finished steel	0·71	0·83	0·564			
					Loss of carbon	0·038	—	—			
					Gain of silicon	—	—	0·260			

TABLE III.—DETAILS OF CHARGE NO. 3.

Finishing.	Composition of Finishing Materials.			Time.	Weight added. Percentage of Total Charge.	Composition of Bath and Added by Finishing Materials.			Composition of Slag.		
Materials.	C.	Mn.	Si.	Hr. Min.		C.	Mn.	Si.	SiO_2.	FeO.	CaO.
Bath	—	—	—	12 55	—	0·415	0·02	0·057	58·6	19·1	4·3
Carnforth pig-iron	4·12	0·48	2·02	12 57	2·00	0·082	0·01	0·040	—	—	—
Ferro-silicon	2·18	2·34	10·78	1 20 / 1 50	2·25	0·049	0·053	0·243	—	—	—
Spiegel	4·77	22·32	1·14	2 15	1·20	0·057	0·268	0·014	—	—	—
Ferro-manganese	5·90	78·00	0·835	Ladle	0·75	0·044	0·585	0·006	—	—	—
			Furnace tapped	2 33	Total	0·647	0·936	0·360			
					Composition of finished steel	0·63	0·82	0·475			
					Loss of carbon	0·017	—	—			
					Gain of silicon	—	—	0·115			

TABLE IV.—DETAILS OF CHARGE NO. 4.

Finishing.	Composition of Finishing Materials.			Time.	Weight added. Percentage of Total Charge.	Composition of Bath and Added by Finishing Materials.			Composition of Slag.		
Materials.	C.	Mn.	Si.	Hr. Min.		C.	Mn.	Si.	SiO_2.	FeO.	CaO.
Bath	—	—	—	9 50	—	0·455	0·02	0·046	—	—	—
Bath	—	—	—	10 4	—	0·44	0·03	0·088	59·2	18·5	5·1
Carnforth pig-iron	3·89	0·18	1·86	10 5	2·00	0·078	0·004	0·037	—	—	—
Ferro-silicon	1·91	1·98	11·53	10 35	1·75	0·033	0·035	0·202	—	—	—
Ferro-silicon	0·43	0·28	24·31	Ladle	0·20	0·001	—	0·049	—	—	—
Ferro-manganese	6·47	78·28	1·21	Ladle	1·10	0·071	0·861	0·013	..	..	..
			Furnace tapped	11 0	Total	0·623	0·93	0·389			
					Composition of finished steel	0·595	0·82	0·536			
					Loss of carbon	0·028	—	—			
					Gain of silicon	—	—	0·147			

* Paper read before the Iron and Steel Institute, May 7, 1920.

† 1896 edition, page. 130.

* "The Elimination of Silicon in the Acid Open-Hearth," Journal of the Iron and Steel Institute, 1902, No. I, page 54.

* Journal of the Iron and Steel Institute, 1902, No. 1, page 73.

TABLE V.—DETAILS OF CHARGE NO. 5.

Finishing.	Composition of Finishing Materials.			Time.	Weight added. Percentage of Total Charge.	Composition of Bath and Added by Finishing Materials.			Composition of Slag.		
Materials.	C.	Mn.	Si.	Hr. Min.		C.	Mn.	Si.	SiO_2.	FeO.	CaO.
Bath	—	—	—	10 50	—	0·22	trace	0·033	—	—	—
Bath	—	—	—	11 12	—	0·20	trace	0·039	—	—	—
Bath	—	—	—	11 38	—	0·175	trace	0·047	56·9	18·7	5·8
Ferro-silicon	2·10	1·25	10·53	11 40	0·25	0·005	0·003	0·026	—	—	—
Carnforth pig-iron ..	4·28	1·75	1·67	11 40	1·00	0·064	0·026	0·025	—	—	—
				11 55	0·50						
Ferro-manganese ..	6·10	77·50	0·18	12 18	1·00	0·061	0·775	0·002	—	—	—
Ferro-silicon	0·15	0·49	25·58	12 18	0·29	—	0·001	0·051	—	—	—
Furnace tapped ..				12 30	Total ..	0·305	0·805	0·151			
Composition of finished steel					.. ..	0·29	0·58	0·198			
Loss of carbon						0·015	—	—			
Gain of silicon						—	—	0·047			

Therefore it is only by atmospheric oxidation that carbon is removed during the period in which the reduction of silicon is taking place.

A much better comparison is afforded by tracing back the history of a finished steel which has been found to contain a much higher percentage of silicon than was expected from the finishing additions. The following tables contain particulars of five such casts of carbon steels. When the high silicon results were obtained the bath samples taken previously to the addition of the finishing materials were analysed for carbon and silicon (and manganese), and the results show the comparatively small loss of carbon from the metal which occurred during the same period in which there was a considerable gain of silicon from the slag.

In Tables I, II, IV and V is given the composition of the bath a little time before the addition of the finishing materials and also immediately prior to their addition, and it is seen that the reduction of silicon was taking place during this period, and continued during the finishing period. In Table I the results show that a little reduction of manganese occurred. In all five charges the slag was highly siliceous. Now it is easily calculated that for carbon to reduce silicon there must be a loss of 0·06 per cent. carbon from the metal for each gain of 0·07 per cent. silicon from the slag, thus:

$$SiO_2 + 2C = Si + 2CO,$$
$$\downarrow \qquad \downarrow$$
24 grammes 28 grammes.

Therefore 0·06 per cent. carbon loss = 0·07 per cent. silicon gain.

The five examples given show decisively that carbon is not responsible for the gain in silicon, for it is seen that the loss of carbon has not been more than 0·04 per cent., whilst the gain in silicon (except in charge No. 5) has been over 0·10 per cent., and in one case (charge No. 2) as high as 0·26 per cent., which, according to the preceding equation, would mean a loss of 0·22 per cent. carbon from the metal. The furnace hearth was fettled previous to charge No. 2, and the high percentage of silicon found in the finished steel is attributed by the authors to the reduction of silicon from the newly sanded hearth. Whenever the hearth has been fettled it is observed that during the working of the next charge the boil is much quieter than when the hearth has held a few charges since being fettled, and the melter finds that, other things being equal, he has to use more iron ore than usual to oxidise the carbon. The authors have had repeated evidence of this tendency for silicon to be reduced from a newly sanded hearth whenever the bath has been allowed to stand too long with a minimum amount of dissolved oxygen present in the metal. If this is allowed to occur, so much ore will be used up in oxidising the reduced silicon before the carbon is attacked to any great extent that the slag will become highly siliceous as in the case of charge No. 2, thus increasing the tendency for silicon to be reduced from the slag.

The authors know of many other cases where the percentage of silicon in the finished steel has been found to be very high whilst the loss of carbon has been comparatively small, but the charges of which details have been given were chosen because no anthracite coal was added to the ladle, which eliminated any likelihood of error which may possibly have occurred in the amount of coal used for recarburising.

Whenever the reduction of silicon from the slag commences, cavities begin to appear in the underside of the metal samples owing to the pressure of escaping gas, the upper surface at first not being marked, but when the reaction becomes vigorous the gas evolved perforates the metal samples so that they become riddled with holes, while the slag covering the metal is observed to rise in the sampling spoon. This phenomenon is easily explained by the theory put forward in a previous paper by one of the authors * that it is iron which decomposes the silica and that the holes in the metal samples are caused by the liberated oxygen according to the equation:

$$SiO_2 + Fe = FeSi + O_2.$$

As the metal in the sampling spoon is enclosed in slag, the oxygen escaping from the decomposed silica of the molten slag below the metal causes depressions or holes

Fig. 1. (For Details see Table VI.)

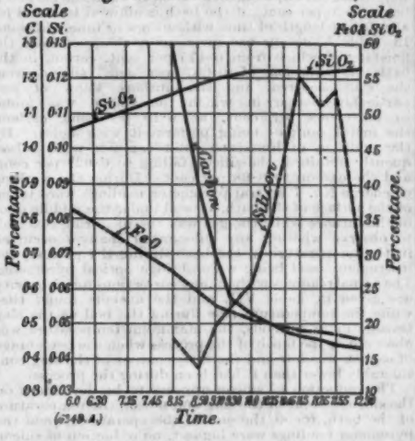
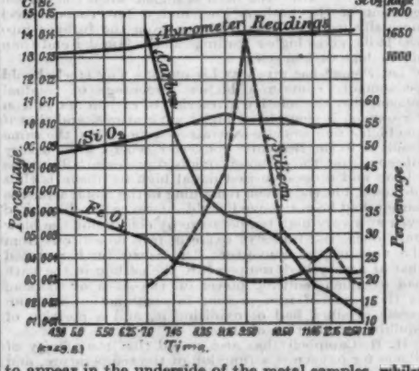


Fig. 2. (For Details see Table VII.)



to appear in the underside of the metal samples, whilst the oxygen escapes from the decomposed silica of the slag above the metal without marking the upper surface of the samples, the latter surface, however, being perforated when the pressure of the oxygen evolved from the slag below the metal is sufficiently high.

In the furnace where the slag is only in contact with the surface of the molten metal, the oxygen is enabled to escape from the decomposed silica without passing through the metal.

Whenever the upper surface of the sample is perforated, a corresponding hole will be found in the underside of the sample where the gas entered into the metal after being liberated from the under layer of slag, and upon fracturing such a sample the metal walls of the interior of the holes marking the passage of the liberated gas are seen to be highly oxidised.

If we consider carbon as the reducing agent according to the equation:—

$$SiO_2 + 2C = Si + 2CO,$$

it would be expected that the samples would always be marked on the upper surface owing to the escape of carbon monoxide formed by carbon from the metal and oxygen from the decomposed silica. This, however, does not occur in practice, for the depressions in the metal samples which indicate the reduction of silicon always make their appearance first in the underside of the sample, and samples are frequently obtained having deep cavities in the underside when the upper surface is perfect. The only time the upper and not the lower surface of the sample is marked is when there is an excess of FeO present in the metal which is being reacted upon by the carbon, thus:—

$$FeO + C = Fe + CO,$$

the marks in this case being caused by the escape o carbon monoxide.

As a further argument against the theory that the reduction of silicon is due to carbon, the authors would like to point out that when 10 per cent. ferro-silicon pig is allowed to melt on the furnace banks and run into the slag (the slag being in proper condition previously), the silicon finds its way into the metal, ostensibly by oxidation and subsequent reduction, and yet the addition of the silicon prevents the loss of carbon from the metal. In the same way, if 75 per cent. ferro-silicon is added, which is of a much lower specific gravity than the slag and therefore floats in the bath, the silicon nevertheless subsequently enters the metal.

In a paper on "Balanced Reactions in Steel Manufacture," by McCance,* he stated that with a highly siliceous slag in contact with iron and carbon the reduction of silicon may take place in two possible ways:—

(1) $SiO_2 + 2C = Si + 2CO - 122$ calories,
(2) $SiO_2 + 2Fe = Si + 2FeO - 51$ calories,

and that in both reactions an increase in temperature will lead to a greater reduction and the formation of more silicon. The improbability of the first reaction occurring has already been discussed. With regard to the second equation, in which Fe is the reducing agent, it will be noticed that it differs from that given above by the authors, but McCance's equation does not explain why holes always appear in the metal samples when the reduction of silicon from the slag is taking place. These holes must be caused by the pressure of escaping gas, and the gas appears to be evolved from the slag, for the holes first show in the underside of the samples.

Further, in considering the possibility of McCance's equation taking place, it must be recognised that the FeO produced would provide a base for the excess SiO_2 in the slag and would be equivalent to the addition of iron ore. Therefore, if no additions of ore were made to the bath and the high temperature maintained, the reaction would soon cease and equilibrium be obtained, and the samples would become free from holes. This, however, is not the case, for in practice the longer the metal is left under a siliceous slag at a very high temperature without ore additions, the more oxide of iron or lime is required to cause the holes to disappear from the samples and so obtain equilibrium in the bath. Again, if it were possible for the reaction given by McCance to continue, there would soon be an excess of FeO in the slag, for two molecules of FeO would be formed for each molecule of SiO_2 decomposed, and according to McCance's investigations † these two oxides are combined in the slag chiefly as fayalite ($2FeO,SiO_2$), so that two molecules of FeO require one molecule of SiO_2. The authors have calculated from the equation given by McCance that there would be a decrease of 2·4 per cent. SiO_2 and an increase of 2·8 per cent. FeO in the slag for a gain of 0·10 per cent. silicon in the metal, taking the weight of metal in the bath as 25 tons and that of the slag as 4 tons. The composition of the slag before the reduction of the silicon is taken as 58 per cent. SiO_2 and 18 per cent. FeO. After the reduction these percentages would be 55·6 per cent. SiO_2 and 20·8 per cent. FeO, thus:—

$$SiO_2 + 2Fe = Si + 2FeO.$$
$$\downarrow \qquad\qquad \downarrow$$
$$\underbrace{28 + 32}_{60} \qquad \underbrace{2(56 + 16)}_{144}$$

Loss of 60 lb. SiO_2 = gain of 144 lb. FeO.
Weight of metal = 25 tons = 56,000 lb.
0·1 per cent. silicon = 56 lb. silicon.

$$\frac{56 \times 60}{28} = 120 \text{ lb. } SiO_2.$$

Loss of 120 lb. SiO_2 = gain of $\frac{144 \times 120}{60} = 288$ lb. FeO.

Weight of slag = 4 tons = 8,960 lb.

Weight of SiO_2 in slag before reduction = $\frac{8,960 \times 58}{100} = 5,196{\cdot}8$ lb. SiO_2.

Weight of FeO in slag before reduction = $\frac{8,960 \times 18}{100} = 1,612{\cdot}8$ lb. FeO.

Weight of SiO_2 in slag after reduction = 5,196·8 − 120 = 5,076·8 lb. SiO_2.

Weight of FeO in slag after reduction = 1,612·8 + 288 = 1,900·8 lb. FeO.

Weight of slag after reduction = 8,960 − 120 + 288 = 9,128 lb.

$\frac{5,076{\cdot}8 \times 100}{9,128}$ = 55·6 per cent. SiO_2 after reduction of silicon.

$\frac{1900{\cdot}8 \times 100}{9128}$ = 20·8 per cent. FeO after reduction of silicon.

The authors have never known the FeO content of the slag to increase while silicon was being reduced from the slag. On the contrary, the FeO content is usually at its lowest and the SiO_2 content at its highest while the reduction of silicon occurs, this being found to be the case in the experiments carried out by McWilliam and Hatfield,‡ previously referred to in the present paper. As an addition to McWilliam and Hatfield's interesting observations the authors of the present paper give details of two special charges, during the working

* "Deoxidation, and the Influence of Lime on Equilibrium in the Acid Open-Hearth Furnace," Journal of the Iron and Steel Institute, 1919, No I, page 257.

* A contribution to a general discussion on "The Occlusion of Gases by Metals," held by the Faraday Society, November 12, 1918.

† Journal of the Iron and Steel Institute, 1918, No. I, page 266.

‡ Journal of the Iron and Steel Institute, 1902, No I, Tables V and VI, pages 58–59.

of which the bath was allowed to stand for several hours without ore or lime additions, the first charge (Table VI, Fig. 1) being an experimental one, and the second charge (Table VII, Fig. 2) being delayed owing to unforeseen circumstances. The weight of each charge was 25 tons, consisting of approximately 45 per cent. hæmatite pig iron and 55 per cent. nickel-chrome scrap.

Table VI.—*Details of Charge No. 6.*

Time. Hr.	Time. Min.	Additions. Material.	Additions. Cwt.	Composition of Metal. Carbon per Cent.	Composition of Metal. Silicon per Cent.	Composition of Slag. SiO_2 per Cent.	Composition of Slag. FeO per Cent.
6	0	(Melted) ..	—	—	—	47·7	36·4
6	30 to 7 15	Ore	20	—	—	—	—
7	45	(Boil)	—	—	—	—	—
8	15	—	—	1·30	0·046	52·3	27·5
8	50	—	—	0·905	0·037	—	—
9	10	—	—	0·70	0·049	54·9	22·4
9	30	—	—	0·58	0·055	—	—
10	0	—	—	0·53	0·061	55·8	20·5
10	25	—	—	0·50	0·077	—	—
10	45	—	—	0·48	0·098	56·0	19·5
11	5	—	—	0·465	0·121	55·9	19·0
11	10	Limestone ..	1	—	—	—	—
11	35	—	—	0·455	0·112	55·8	18·9
11	55	—	—	0·44	0·117	—	—
12	0	Limestone ..	1¼	—	—	—	—
12	30	Finishing materials ..	—	0·43	0·068	56·3	17·7

In Table VI it is seen that the first limestone addition (at 11 hours 10 minutes) prevented the further reduction of silicon, the lime evidently combining with the excess SiO_2 in the slag and lowering the FeO and SiO_2 content a little by dilution. The second lime addition (at 12 hours 0 minutes) must have displaced FeO from the slag, which oxidised the silicon in preference to the carbon.

It is also interesting to note that during the finishing of charge No. 6, silicon was rapidly reduced from the slag, the percentage of this element being very high in the finished steel, and there was less loss of carbon, manganese and chromium than normally occurred, showing that the percentage of dissolved oxygen in the bath must be very low during the period in which silicon is being reduced.

Table VII.—*Details of Charge No. 7.*

Time. Hr.	Time. Min.	Additions. Material.	Additions. Cwt.	Composition of Metal. Carbon per Cent.	Composition of Metal. Silicon per Cent.	Composition of Slag. SiO_2 per Cent.	Composition of Slag. FeO per Cent.	Pyrometer Reading of Bath.
								deg.
4	30	(Melted) ..	—	—	—	48·4	35·5	1,610
5	0 to 5 50	Ore ..	18	—	—	—	—	—
6	25	(Boil) ..	—	—	—	—	—	—
6	30	—	—	—	—	—	—	1,620
7	0	—	—	1·43	0·027	51·8	28·2	—
7	45	—	—	0·985	0·036	53·9	24·0	—
8	30	—	—	—	—	—	—	1,645
8	35	—	—	0·68	0·057	55·7	22·7	—
9	15	—	—	0·59	0·078	57·5	20·4	—
9	50	—	—	0·565	0·139	57·1	19·7	—
10	0	—	—	—	—	—	—	1,655
10	0 to 10 15	Ore ..	5	—	—	—	—	—
10	45	—	—	—	—	—	—	1,650
10	50	—	—	0·48	0·053	55·9	19·9	—
10	0 to 11 15	Ore .. 7 / Limestone	7 / 1	—	—	—	—	—
11	45	—	—	0·275	0·037	54·3	22·5	1,655
12	15	—	—	0·245	0·045	54·8	21·7	—
12	20	Limestone ..	1	—	—	—	—	—
12	50	—	—	0·17	0·029	54·8	21·2	—
1	0	—	—	—	—	—	—	1,660
1	10	Finishing materials ..	—	0·135	0·027	54·7	21·4	—

The following are details showing the loss of carbon compared with the gain of silicon during the finishing of charge No. 6 :—

	Carbon.	Silicon.
Bath immediately before addition of finishing materials...	0·43	0·068
Added by finishing materials	0·28	0·255
Total	0·71	0·323
Composition of finished steel	0·685	0·568
Loss of carbon ...	0·025	—
Gain of silicon ...	—	0·245

The composition of the finished steel from charge No. 7 was quite normal.

During the working of both charges the greatest reduction of silicon took place whilst the FeO content of the slag and the rate of oxidation of the carbon were lowest, thus confirming the results obtained by McWilliam and Hatfield; but if carbon were the reducing agent, this element would have been removed more rapidly during the period in which the reduction of silicon occurred.

The main reason why many metallurgists favour the theory that the reduction of silicon is effected by the carbon is that it is more easily reduced when the percentage of carbon in the bath is high. Dr. McCance, in the paper referred to on page 11, states that the reduction of silicon during the finishing stages, when the carbon is in the region of 0·15 per cent. to 0·20 per cent., is practically negligible, and that this tends to show that carbon must be the reducing agent. This, however, does not follow, for it is a well-known fact that when there is a low percentage of carbon in the bath, the FeO content of the slag has a tendency to increase and the SiO_2 content thereby to decrease (see Table VII), and more oxygen is liable to be dissolved in the metal owing to there being insufficient carbon present to effect deoxidation. Consequently it would be impossible for silicon to enter the metal in the presence of dissolved FeO, and the decrease in the percentage of SiO_2 would diminish the tendency for silicon to be reduced from the slag. Dr. McCance, however, admits that in the acid electric furnace the reduction of silicon is quite appreciable and that it is possible to reduce 0·20 per cent. to 0·30 per cent. direct from the slag, which would mean a loss of 0·17 per cent. to 0·26 per cent. carbon from the metal if carbon were the reducing agent.

The authors have found that quite an appreciable amount of silicon can be reduced from a very siliceous slag in the acid open-hearth furnace, when the carbon is below 0·20 per cent., if the bath is allowed to stand for a sufficient length of time without ore or lime additions. In Table V details are given of a charge during the finishing of which from 0·175 per cent. carbon in the bath, a reduction of 0·047 per cent. silicon from the slag occurred, and the authors know of one particular charge in which the silicon was found to be 0·088 per cent. at 0·10 per cent. carbon, the metal samples being perforated with holes. By the addition of limestone solid samples were subsequently obtained, the silicon falling to 0·027 per cent. and the carbon to 0·08 per cent. During the working of charge No. 7 several pyrometer readings were taken of the surface of the bath, viewed under the middle door of the furnace while the gas was absent during reversal, to observe whether any substantial changes occurred in the temperature of the bath during the process, the instrument used being a Cambridge optical pyrometer. The actual readings without any corrections for emissivity are given in Table VII, and the authors found that while the temperature rose during the boil as the slag became more siliceous, the maximum temperature was observed at the finish of the process when the percentage of carbon was low and the SiO_2 content of the slag considerably lower than it had been during the process.

The reduction of silicon appears to be dependent on the silica content of the slag and not on the temperature of the bath, for at the end of the operation, when the pyrometer readings were highest, no reduction of silicon occurred. Similar readings have been repeatedly obtained by the authors, showing that the temperature required to "kill" the bath is higher when the carbon content of the bath is low, and a low carbon steel normally worked, when running from the furnace into the ladle, gives higher readings at the launder end than does a high carbon steel.

Dr. Stead* has given as his reasons why steel should occasionally contain a higher percentage of residual silicon, that the relative attraction of carbon and silicon for oxygen is changed at high temperatures, and that if too high a temperature is attained we may get the same result as in the Bessemer converter, where, using a very siliceous iron, the carbon is oxidised preferentially to the silicon and a decarburised metal high in silicon is thus obtained, but the silicon remaining in the metal after the carbon had been removed could, however, be eliminated even at a very high temperature by continuing the blow until dense red fumes of oxide of iron passed out from the nose of the converter. Dr. Stead further stated that at a very high temperature the carbon in the bath had as much reducing power on the silica of the slag as the oxide of iron present in combination with an excess of silica had of oxidising it, and a position of equilibrium was thus obtained.

H. H. Campbell† has also stated that the affinity of silicon for oxygen is a function of the temperature, and that in the Bessemer converter the metal may contain as much as 1 per cent. silicon if blown sufficiently hot, but that the open-hearth cannot rival the converter in producing high silicon metal by non-combustion.

With regard to the foregoing observations by Stead and Campbell, the authors of the present paper are of the same opinion as expressed by McWilliam and Hatfield in their reply to Dr. Stead's discussion of their paper,‡ and also in their paper on "Acid Open-Hearth Manipulation,"§ that the necessarily acid slag produced by a very high temperature may have been the real cause of the high silicon remaining in the metal when the normal blow was finished, and that the afterblow referred to by Dr. Stead would by oxidation of the iron dilute the slag to the composition necessary for the elimination of the remaining silicon.

Similarly, in the acid open-hearth furnace it is possible by maintaining a very high temperature to obtain such a highly siliceous slag that it refuses to take up any more silicon from the metal until a sufficient quantity of a base such as FeO or CaO has been added to combine with the excess SiO_2 in the slag and so effect equilibrium. If the metal is allowed to remain under a siliceous slag for a long period without additions of ore or lime, the percentage of carbon in the bath will become almost stationary while the silicon is being rapidly reduced from the slag, the oxidation of the carbon being prevented by the silicon passed back into the metal.

A high temperature is certainly essential for the reduction of silicon to occur, but it does not follow that oxygen has a greater affinity for carbon than for silicon at such a temperature, for the subsequent addition of iron ore, say, 1 cwt. to a 25-ton bath of metal containing a fairly high percentage of silicon, would only reduce the temperature of the bath a few degrees, and yet it would be found on analysis that some of the silicon had been oxidised in preference to the carbon, that is, if the oxide of iron added was in excess of that required by the silica of the slag, and the addition of sufficient lime would have the same effect. If the bath is then allowed to remain for a considerable time without further ore or lime additions, the silicon oxidised will be reduced and passed back into the metal, to be again oxidised when the next addition of ore or lime is made. It is also the authors' experience that no matter what the temperature of the molten bath may be, the addition of silicon will at all times prevent the loss of carbon from the metal on account of the former element being more readily oxidised. Therefore it appears to be very improbable that carbon can displace oxygen from combination with silicon as indicated by the equation :

$$SiO_2 + 2C \rightleftharpoons Si + 2CO.$$

The authors are aware that an attempt to represent by simple chemical equations the complex reactions which take place in the open-hearth or any other metallurgical process cannot be satisfactorily accomplished, for it is not possible to illustrate by such means all the conflicting cross-reactions which occur, there being far too many factors to take into consideration.

Therefore these reactions can only be represented to a very limited extent by such equations as those discussed in the present paper. The authors, however, believe that they are nearer the truth by stating that iron, the element always present in such great excess, is a far more powerful reducing agent than carbon, and that it is iron and not carbon which effects the reduction of silicon in the acid open-hearth process.

With regard to the thermo-chemistry of the subject, the reaction which takes place when silicon is reduced from the slag is necessarily endothermic. The authors have been unable to obtain satisfactory data relating to the value of the heat of formation of silicide of iron, but there is no doubt that the reaction, as expressed by the equation :

$$SiO_2 + Fe = FeSi + O_2,$$

would be attended with the absorption of heat.

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* Journal of the Iron and Steel Institute, 1902, No. I, page 73.

† "The Manufacture and Properties of Structural Steel," 1896 edition, page 130.

‡ Journal of the Iron and Steel Institute, 1902, No. I, page 77.

§ *Ibid.*, 1904, No. II, page 206.

The Benevolent Fund of the Institution of Mechanical Engineers.—The Committee of Management desire to direct attention to the above fund, which is available for the financial assistance of those who are or have been members of the Institution, and for the relatives or dependents of such persons. It is thought that possibly some who are qualified to receive assistance and who are in financial hardship owing to the demobilisation of H.M. Forces, the closing of the munitions factories, or other causes arising out of the war or otherwise, may not be aware of the existence of the fund. Forms of application for assistance may be obtained from the Hon. Secretary of the Benevolent Fund, Storey's Gate, Westminster, S.W. 1. Special arrangements are made to preserve the greatest possible secrecy in dealing with applications.

The Institution of Water Engineers.—The twenty-fifth summer general meeting will be held at Birmingham, on Thursday, Friday and Saturday, June 10, 11 and 12, when the following papers will be read and discussed : (1) "The Madras City Waterworks," (Part II, details of construction), by Mr. J. W. Madeley, M.A., M.Inst.C.E., of Madras ; (2) "The Water Resources of the Birmingham District," by Professor W. S. Boulton, D.Sc., F.G.S., of Birmingham University ; (3) "The Application of Turbine Pumps to Water Supply," by Mr. C. F. Bekenn ; (4) "The Birmingham Scale of Charges for Water," by Mr. E. Antony Lees, O.B.E., Assoc.M.Inst.C.E. ; (5) "The Construction of Waterworks on Land Subject to Subsidence," by Mr. F. C. Cook, Assoc.M.Inst.C.E., and Mr. R. C. Moon, Assoc.M.Inst.C.E. Applications for tickets and cards must be delivered to the Secretary, 20, Victoria-street, S.W. 1, not later than Thursday, June 3.

The Royal Institution.—The annual meeting of the members of the Royal Institution was held on Saturday, the 1st inst., Sir James Crichton-Browne, treasurer and vice-president, in the chair. The annual report of the Committee of Visitors for the year 1919, testifying to the continued prosperity and efficient management of the Institution, was read and adopted, and the report of the Davy Faraday Research Laboratory Committee was also read. Sixty-four new members were elected during the year and 62 lectures and 19 evening discourses were delivered. The books and pamphlets presented amounted to 193 volumes, making, with 399 volumes (including periodicals bound) purchased by the managers, a total of 592 volumes added to the library in the year. Thanks were voted to the president, treasurer and secretary, to the committees of managers and visitors, and to the professors, for their services to the Institution during the past year. The following gentlemen were unanimously elected as officers for the ensuing year : President, The Duke of Northumberland ; treasurer, Sir James Crichton-Browne ; secretary, Colonel Edmond H. Hills ; 15 managers and 15 visitors.